STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

FRANK F. MERRIAM, Governor

EARL LEE KELLY, Director of Public Works

DIVISION OF WATER RESOURCES

BULLETIN NO. 48-A

S A N L U I S R E Y R I V E R
I N V E S T I G A T I O N

1936

Department
seal

Sacramento, 1937

TABLE OF CONTENTS

TABLE OF CONTENTS, Continued.

Appendix A consists of eight tracings twenty-eight inches by forty inches in size. Two show the topography of the Bonsall dam site at a scale of one inch equals one hundred feet with five foot contours and the location of the various exploratory workings. One shows profiles of the various explorations and the classifications of the materials encountered. Five show the topography of the Bonsall reservoir at a scale of one inch equals four hundred feet with a contour interval of ten feet.

Since these tracings were so large and since their value depends to a large extent on the size of the scale, they have not been reproduced for general distribution. Black line tracings from which reproductions can be made have been filed with each of the cooperative agencies; the Works Progress Administration in San Diego, the County of San Diego, the City of Oceanside, and the Carlsbad Mutual Water Company.

APPENDIX B.

TOPOGRAPHY OF MONSERATE DAM SITE AND RESERVOIR

Appendix B consists of four tracings twenty-eight inches by forty inches in size. One shows the topography of the Monserate dam site at a scale of one inch equals one hundred feet with five foot contours and the profiles of the explorations with a classification of the materials encountered. Three show the topography of the Monserate reservoir at a scale of one inch equals four hundred feet with a contour interval of ten feet.

Since these tracings were so large and since their value depends to a large entent on the size of the scale, they have not been reproduced for general distribution. Black line tracings from which reproductions can be made have been filed with each of the cooperative agencies; the Works Progress Administration in San Diego, the County of San Diego, the City of Oceanside, and the Carlsbad Mutual Water Company.

LIST OF TABLES

LIST OF PLATES

LIST OF PLATES, Continued

ACKNOWLEDGEMENT

This bulletin has been prepared by the Division of Water Resources of the Department of Public Works of the State of California in cooperation with the Federal Government Works Progress Administration, the County of San Diego, the City of Oceanside, and the Carlsbad Mutual Water Company.

The respective shares of each of the cooperating agencies in the financing of this investigation were as follows:

Works Progress Administration	$ 22,000.00
Division of Water Resources	2,500.00
County of San Diego	1,000.00
City of Oceanside	750.00
Carlsbad Mutual Water Company	750.00
	$ 27,000.00

Additional valuable aid was furnished the investigation as follows:

By Messers. Ernest Rensse, B. A. Sweet, and R. M. Widenham, the owners of the Bensall dam site and by Mr. Charles E. Cooper, the owner of the Monserate dam site.

By the City of Oceanside, in furnishing free of charge, office space, light and telephone facilities.

By the County of San Diego, in the transporation of equipment to and from the work.

By the Carlsbad Mutual Water Company, the City of San Diego and other divic agencies, public officials and private individuals, through the loan of equipment and the furnishing data and valuable assistance.

The Division of Water Resources wishes to express its appreciation of the cooperation furnished by all the members of the works Progress Administration both in the field and in its San Diego office. The morale of the worker assigned to the project was at all times high and their interest in the investigation and desire to help towards a worth-while result were always apparent.

ORGANIZATION

S T A T E O F C A L I F O R N I A

Frank F. Merriam	Governor
Earl Lee Kelly	Director of Public Works
Edward Hyatt	State Engineer

This bulletin was prepared under the direction of
A. D. Edmonston, Deputy State Engineer

by

ROBERT L. WING, Associate Hydraulic Engineer

Assisted by

P. H. Van Etten, Senior Hydraulic Engineer, who acted in an advisory capacity in the preliminary stages of the investigation

Chester Marliave	Engineer - Geologist
J. L. James	Delineator

J. J. Haley, Jr., Administrative Assistant

W O R K S P R O G R E S S A D M I N I S T R A T I O N

Frank Y. McLaughlin	Administrator
Ralph Wadsworth	Deputy Administrator

DISTRICT NO. 12

George B. White	Director
R. M. Gregory	Chief Engineer
E. L. Freeland	Supervisor, Division of Operations

Assistants

J. M. Graves, Field Superintendent	Thos. M. Hye, General Foreman.
Byron Johnson, Transitman	Lee Arbuckle, Topographer
C. M. Watson, Topographer	Harold Clark, Topographer
Roland Curran, Delineator	Dallas Kime, Delineator

FOREWORD

In 1935, the Division of Water Resources, Department of Public Works, State of California, published Bulletin No. 48, "San Diego County Investigation". In that Bulletin were presented "detailed data and information on the water supplies and agricultural lands of San Diego County; the present status of irrigation and domestic and municipal water supply developments; the utilization of water supplies from surface and underground sources; the irrigable lands and water requirements and the domestic and municipal water requirements of the metropolitan area; the flood flows of the principal streams and probable frequency of occurrence". The San Luis Rey River was included with the other San Diego County streams, in that bulletin. The data and information presented, however, was general in character and no detailed plans of development or estimates of cost were made.

This report presents the data and information obtained from an investigation of the San Luis Rey River Basin which covered a revision of the estimates of runoff given in Bulletin No. 48; the amount of storage available in reservoir sites at Bonsall and above Monserate Narrows; the probable yields available from the San Luis Rey River; the results of geologic investigations of the damsites including surface explorations, tunnels and wells; and the probable costs of developing the reservoirs.

CHAPTER I

INTRODUCTION, SUMMARY AND CONCLUSIONS

In 1933-34 the Division of Water Resources made a study of the hydrology of San Diego County. The results of this study were presented to the public in Bulletin No. 48, "San Diego County Investigation". Analyses of the probable full natural flows of the various streams, the probable sizes and frequencies of the floods which might be expected to occur on these streams, the need of the county for additional water supplies, and a plan for the full development of the San Diego River for conservation and flood control purposes were presented in that bulletin.

In 1935 the City of Oceanside, the Carlsbad Mutual Water Company, and the County of San Diego, realizing that the present draft on the San Luis Rey River, the source of water supply of the City and the Water Company, was approaching the maximum safe yield of that stream without additional development, requested the State Division of Water Resources to sponsor an investigation of the San Luis Rey River by the Works Progress Administration of the Federal Government. Accordingly, the Division filed an application for such an investigation with the Works Progress Administration on September 3, 1935. This application was approved by the Federal officials December 18, 1935 and work was commenced March 11, 1936. The Division of Water Resources, acting for the sponsoring agencies, agreed to furnish technical supervision, the well drilling rig, and office supplies. The Works Progress Administration agreed to supply all labor, both common and technical, and the materials to be used in the field. However, the Works Progress Administration had difficulty in finding qualified technical workers both in the field and in the office and consequently it became necessary to modify the original plan of operation. More money

was spent on the geological exploration of the dam sites and on topographic surveying and less on analyses of the data obtained than would have been the case had adequate technical help been available. All the analyses have been made by the employes of the Division of Water Resources.

SUMMARY

The field work of this investigation included geological explorations of two dam sites on the San Luis Rey River; one, two miles west of Bonsall at the State Highway crossing, the other, at the Monserate Narrows four miles west of Pala; and topographic surveys of both dam sites and of the corresponding reservoir basins. The office analyses consisted of estimating the runoff available for conservation, the capacities of the reservoirs, the probable yield for consumptive use, and the costs of such a water supply.

Water Supply

The San Luis Rey River drains a basin of some 565 square miles in extent. The Henshaw Dam at the lower end of the Warner Valley controls the flow from the upper 206 square miles of this basin. The Escondido Mutual Water Company diverts water out of the basin. The Rincon and Pala Indians and numerous other private owners pump water from the river bed for the irrigation of the overlying river bottoms.

Had the present upstream diversions been in effect during the 48-year period from 1887 to 1935, the mean seasonal flow past the Bonsall dam site would have been 23,170 acre-feet. This flow, as shown in the following table, varied from season to season, between wide limits.

SEASONAL RUNOFF
OF
SAN LUIS REY RIVER AT BONSALL DAM SITE
WITH EXISTING UPSTREAM DIVERSIONS

Season	Runoff, in Acre-feet	Season	Runoff, in Acre-feet	Season	Runoff, in Acre-feet
1887-88	13,690	1903-04	2,670	1919-20	9,400
1888-89	27,340	1904-05	22,390	1920-21	2,240
1889-90	43,930	1905-06	56,120	1921-22	56,530
1890-91	38,890	1906-07	43,330	1922-23	14,580
1891-92	17,750	1907-08	13,750	1923-24	8,520
1892-93	21,500	1908-09	25,750	1924-25	4,150
1893-94	17,410	1909-10	25,460	1925-26	16,060
1894-95	88,260	1910-11	18,020	1926-27	75,680
1895-96	5,020	1911-12	6,530	1927-28	7,100
1896-97	14,200	1912-13	3,180	1928-29	7,230
1897-98	2,920	1913-14	19,740	1929-30	10,930
1898-99	1,350	1914-15	76,120	1930-31	4,610
1899-00	1,550	1915-16	160,970	1931-32	47,100
1900-01	8,520	1916-17	21,940	1932-33	9,410
1901-02	5,630	1917-18	15,250	1933-34	3,410
1902-03	7,450	1918-19	8,340	1934-35	10,190
48-year (1887-1935) mean seasonal runoff					23,170

In the season 1898-1899 only 1,350 acre-feet of water would have passed the dam site while in the season 1915-16 there would have been a flow of 160,970 acre-feet. This variation is periodic as well as seasonal, as is shown by a comparison of the seven-year means for the periods 1897-1904, 4,300 acre-feet and 1913-1920, 44,540 acre-feet, which shows that the wet period produced over 10 times as much runoff as the dry period.

Yield of Reservoirs

A large amount of storage space is needed to conserve surplus water from wet periods for use in dry periods. Studies of the operation of the Bonsall reservoir for conservation show that a reservoir capable of storing 49,170 acre-feet of water in the Bonsall basin, would produce a net safe yield of 6,020 acre-feet; that with a reservoir of 95,780 acre-feet capacity the net safe yield can be increased to 8,530 acre-feet; and that 162,610 acre-feet of storage will provide a net safe yield of 12,730

acre-feet per season or, accepting a 25 per cent deficiency during the last four years of the exceptionally dry period 1895-1905, a seasonal yield of 14,180 acre-feet. In addition to the storage space provided by a reservoir in the Bonsall basin, there is also available some 12,300 acre-feet of underground storage space in the Mission basin between the Bonsall dam site and Oceanside which should yield an additional 2,000 acre-feet of water per season.

Storage Reservoirs

A reconnaissance survey of the San Luis Rey River basin from Oceanside to Rincon was made in search of possible reservoir and dam sites. This survey indicated that the most favorable dam sites were in the Bonsall Narrows at the State Highway crossing, storing water in the Bonsall basin and at the Monserate Narrows, storing water in the Pala Basin. Both of these sites have been explored and the topography mapped.

Bonsall Dam and Reservoir

The exploration and geological investigation of the Bonsall dam site show that an adequate foundation for an earth fill dam could be prepared with only a few feet of excavation on the abutments and with a maximum excavation of about 55 feet in the river bed.

The topographic surveys of the reservoir site show that a dam providing an 80 foot depth of water would store 49,170 acre-feet, a 100 foot depth would store 95,780 acre-feet, and a 120 foot depth would store 162,610 acre-feet.

The preliminary design of an earth fill dam for this location provided for a twenty-foot free board between the spillway lip and the crest of the dam; an upstream slope of 2.5:1; a crest width of 50 feet; a down stream slope of 2.5:1 for the top 40 feet of height and of 3:1 for the remaining distance; an upstream impervious section with a ten foot crest

width, a down stream slope of 1:1, and an upstream slope of 2.5:1 faced with a concrete paving. Excavation in the river bed extended to bedrock under the impervious section but only through about two feet of stripping under the pervious section. The capital and annual costs of such a dam for heights of 100 and 140 feet are shown in the following table:

COSTS OF BONSALL RESERVOIRS

Storage Capacity, in acre-feet	49,170	162,610
Height of dam, in feet	100	140
*Seasonal yield with no deficiency, in acre-feet	6,020	12,730
*Seasonal yield with 25 per cent deficiency, in acre-feet		14,180
*Seasonal yield including Mission Basin with no deficiency, in acre-feet	8,020	14,730
*Seasonal yield including Mission Basin with 25 per cent deficiency, in acre-feet		16,180
*Increase in seasonal yield including Mission Basin with no deficiency over present yield of 5,900 acre-feet, in acre-feet	2,180	8,830
*Increase in seasonal yield including Mission Basin with 25 per cent deficiency over present yield of 5,900 acre-feet, in acre-feet		10,280
CAPITAL COSTS - TOTALS	$3,759,000	$5,316,000
Per acre-foot of storage	76.40	32.70
Per acre-foot of seasonal yield with no deficiency	624.00	418.00
Per acre-foot of seasonal yield with 25 per cent deficiency		375.00
Per acre-foot of seasonal yield including Mission Basin with no deficiency	469.00	361.00
Per acre-foot of seasonal yield including Mission Basin with 25 per cent deficiency		329.00

*The small safe yields as compared with reservoir capacities are caused by the extremely dry period 1897-1904 in which the average runoff was only 4,300 acre-feet. They do not include any possible savings of present natural losses by transpiration from the vegetation which would be cleared from the reservoir basin.

Per acre-foot of increase in seasonal yield including Mission Basin with no deficiency	1,640.00	602.00
Per acre-foot of increase in seasonal yield including Mission Basin with 25 per cent deficiency		517.00
ANNUAL COSTS - TOTALS	$233,000.00	$331,000.00
Per acre-foot of storage	4.74	2.04
Per acre-foot of seasonal yield with no deficiency	38.70	26.00
Per acre-foot of seasonal yield with 25 per cent deficiency		23.30
Per acre-foot of seasonal yield including Mission Basin with no deficiency	29.10	22.50
Per acre-foot of seasonal yield including Mission Basin with 25 per cent deficiency		20.50
Per acre-foot of increase in seasonal yield including Mission Basin with no deficiency	109.90	37.50
Per acre-foot of increase in seasonal yield including Mission Basin with 25 per cent deficiency		32.20

The annual costs per acre-foot of yield listed in the above table are based on the assumption that the water users would pay the full costs of the dam and reservoir with interest charges at five per cent per annum and a forty year amortization period. Any grants from the Federal government for the flood control provided or any reduction in the interest rate through Federal financing may reduce these costs materially.

Monserate Dam and Reservoir

The exploration of the Monserate dam site showed that an excavation of about 100 feet in depth would be necessary over several hundred feet of stream bed and that the right abutment was so fractured and disintegrated that a water tight facing would be required over the reservoir face of the ridge. A preliminary comparison of the costs of the Bonsall and Monserate

dams was made. This showed that the Bonsall dam would probably be much less costly than the Monserate dam. Consequently, no detailed studies have been made of the costs of storage or of seasonal yields from the Monserate site.

Flood Control

The operation of the 162,610 acre-foot reservoir at Bonsall for a seasonal yield of 14,180 acre-feet would so regiment the flow of the river that uncontrolled flows would pass the dam only in seasons of major floods. The crest flows of these floods would be very materially reduced in passing through the spillway. An analysis of the estimated once-in-250 year flood shows that the passage of that flood through the spillway would have reduced its crest flow from 80,500 second-feet to 53,100 second-feet, or about 34 per cent. The reductions in the crest flows of more frequent floods would be even greater.

CONCLUSIONS

The principal conclusions of this investigation may be summarized as follows:

1. Based on the period 1887-1935, the mean seasonal runoff from the area between Henshaw Dam and the Bonsall dam site is 23,170 acre-feet. The runoff from the drainage basin between the dam site and Oceanside is given in Bulletin No. 48 as 3,370 acre-feet. The total mean seasonal runoff available at Oceanside is 26,540 acre-feet.

2. The present draft of approximately 5,900 acre-feet is approaching the maximum yield which may be obtained with reasonable safety.

3. A reservoir storing 162,610 acre-foot of water in the Bonsall basin could have been operated during the period 1887-1935 to produce a seasonal yield of 14,180 acre-feet by taking a twenty-five per cent deficiency in the driest years. Probably 2,000 acre-feet per season of the inflow below

the reservoir could have been conserved by underground storage in the Mission Basin. The total yield from the stream for the period would have been about 16,180 acre-feet per season. This would have provided a reasonably safe yield of 10,280 acre-feet in addition to the present draft.

4. Satisfactory foundations may be prepared at the Bonsall dam site with only a few feet of excavation on the abutments and a maximum of about 55 feet of excavation in the stream bed.

5. A reservoir storing 162,610 acre-feet of water in the Bonsall basin could be formed by the construction of a dam 120 feet in height from stream bed to spillway lip. Under present conditions an earth dam with a freeboard of twenty feet above the spillway lip and the necessary reservoir lands would cost about $5,316,000. The annual cost would be about $331,000 or $20.50 per acre-foot of reasonably safe yield or $32.20 per acre-foot of increase in yield over present draft.

6. The spillway of the Bonsall dam can be so designed that the smaller floods may be reduced to purely nominal flows and that a major flood such as might be expected to occur at an interval once in 250 years could be reduced more than one-third.

7. The Monserate dam site is unsatisfactory because of the excessive depth of river fill in the stream bed and of the permeable nature of the ridge forming the right abutment which would require an expensive impervious blanket on the reservoir side.

The preliminary analyses of this investigation have established the suitability of the Bonsall site for the construction of an earth dam and have determined within reasonable limits of error the probable runoff which would have been available for conservation during the period 1889-1935. However, the lack of sufficient technical help prevented the necessary additional analyses of reservoir operation and detailed estimates of costs which if made might show increased yields and

reduced costs per acre-foot of additional yield. Further analyses could include, among others, the following:

1. Estimate of the present losses from the underground basins through transpiration by natural vegetation in the river bed and the increase in yield which could be obtained by the elimination or reduction of these losses.

2. Estimate of the increase in yield which might be obtained by the reduction of the estimated evaporation losses through utilization of storage in the Bonsall and Pala underground basins.

3. Estimate of the costs of spreading works designed to increase percolation into the underground basins and of pumping plants strategically located to utilize more nearly the full capacities of the underground basins.

CHAPTER II

HYDROGRAPHY

The San Luis Rey River is the most northerly of the San Diego County streams whose drainage basins lie almost wholly within the boundaries of San Diego County. Rising in the Warner Mountains at an elevation of about 5,000 feet above sea level, the river flows in a southwesterly direction across the Warner Valley, skirts the southerly base of Palomar Mountain in a deep, narrow gorge and thence flows in a general westerly direction, through a series of valleys and narrows, to its point of discharge into the Pacific Ocean at Oceanside. Its major tributaries are Pauma Creek, which drains the western slope of Palomar Mountain and enters the river several miles east of Pala, and Keys and Moosa Canyons, which drain the mesa lands south of the river and enter from the south between Monserate Mountain and Bonsall. The drainage basin above Oceanside, shown on Plate I, "Drainage Basin of San Luis Rey River", has an area of 565 square miles, is about 56 miles long and has an average width of 10 miles.

The construction of Henshaw Dam, which has created a reservoir of 203,600 acre-feet capacity at the lower end of the Warner Valley, has effectively controlled the flow from the upper 206 square miles of the San Luis Rey River drainage basin. Only in the wettest years will any uncontrolled flows pass the Henshaw Dam. The lower 359 square miles of drainage basin, including the western slope of Palomar Mountain which rises to an elevation of over 6,000 feet above sea level comprise one of the largest sources of undeveloped water in San Diego County.

Full Natural Flow

Estimates of the full natural flows of the San Luis Rey River from the drainage basins above Henshaw Dam, between Henshaw Dam and "near

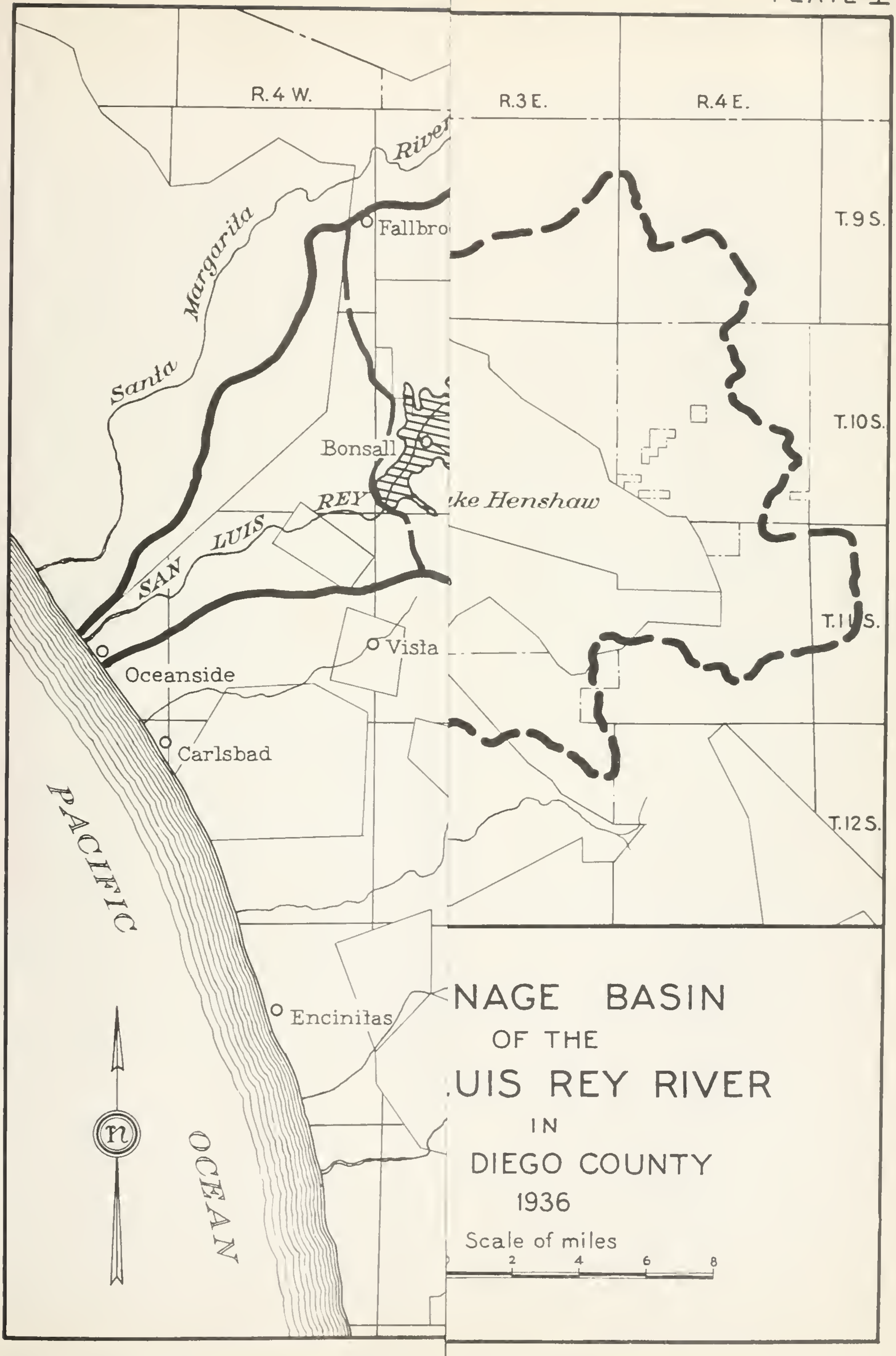
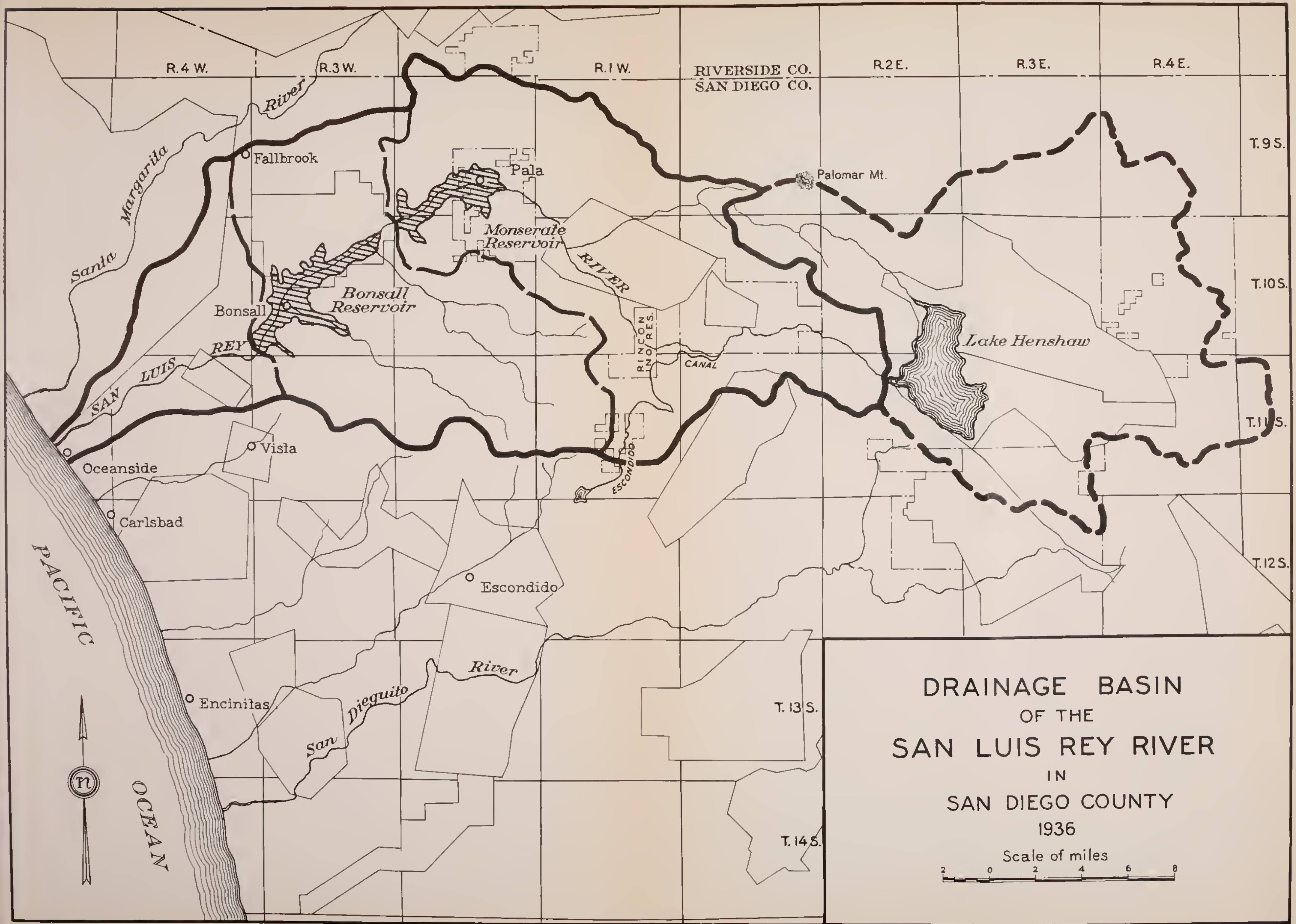

R. 4 W.
R. 3 E.
R. 4 E.
T. 9 S.
T. 10 S.
T. 11 S.
T. 12 S.
Santa Margarita River
Fallbro
Bonsall
SAN LUIS REY
ake Henshaw
Oceanside
Vista
Carlsbad
Encinitas
PACIFIC OCEAN
NAGE BASIN
OF THE
UIS REY RIVER
IN
DIEGO COUNTY
1936
Scale of miles
2
4
6
8

PLATE I


R.4 W.
R.3 W.
R.1 W.
RIVERSIDE CO.
SAN DIEGO CO.
R.2 E.
R.3 E.
R.4 E.
T.9 S.
T.10 S.
T.11 S.
T.12 S.
T. 13 S.
T. 14 S.
Santa Margarita River
Fallbrook
Pala
Palomar Mt.
Monserate Reservoir
Bonsall Reservoir
Bonsall
RIVER
RINCON INO RES.
CANAL
Lake Henshaw
SAN LUIS REY
Vista
Oceanside
ESCONDIDO
Carlsbad
Escondido
PACIFIC OCEAN
River
San Dieguito
Encinitas
DRAINAGE BASIN
OF THE
SAN LUIS REY RIVER
IN
SAN DIEGO COUNTY
1936
Scale of miles
2 0 2 4 6 8

Bonsall", and between "near Bonsall" and Oceanside were presented in Bulletin No. 48. These estimates were based on all the available stream flow measurements and data on the use of water for irrigation and other purposes which were obtainable at the time those estimates were made. However, an irrigated area survey, made in 1934-35, indicated that the irrigation uses in the area below Henshaw Dam had been underestimated in the preparation of Bulletin No. 48. For this reason, it has been necessary to revise the estimates therein presented. The revised estimates of full natural flow are presented in Table 1, "Full Natural Flow of San Luis Rey River". A comparison with the estimates presented in Bulletin No. 48 shows that this revision increased the estimated mean seasonal full natural runoff by 2,460 acre-feet.

Available Flow

All of the full natural flow, however, is not available for conservation at downstream points. The Escondido Mutual Water Company, the Rincon and Pala Indian Reservations and numerous private irrigators have prior rights to the flow in the stream. The Rincon Indians also have a prior right to water from above the Henshaw Dam, which, when exercised, increases the downstream flow by the amount of the return flows from their irrigation.

The Rincon Indians right, conceded by the upstream divertors, is to the first three second feet originating above their reservation.

Bonsall", and between "near Bonsall" and Oceanside were presented in Bulletin No. 48. These estimates were based on all the available stream flow measurements and data on the use of water for irrigation and other purposes which were obtainable at the time those estimates were made. However, an irrigated area survey, made in 1934-35, indicated that the irrigation uses in the area below Henshaw Dam had been underestimated in the preparation of Bulletin No. 48. For this reason, it has been necessary to revise the estimates therein presented. The revised estimates of full natural flow are presented in Table 1, "Full Natural Flow of San Luis Rey River". A comparison with the estimates presented in Bulletin No. 48 shows that this revision increased the estimated mean seasonal full natural runoff by 2,460 acre-feet.

Available Flow

All of the full natural flow, however, is not available for conservation at downstream points. The Escondido Mutual Water Company, the Rincon and Pala Indian Reservations and numerous private irrigators have prior rights to the flow in the stream. The Rincon Indians also have a prior right to water from above the Henshaw Dam, which, when exercised, increases the downstream flow by the amount of the return flows from their irrigation.

The Rincon Indians right, conceded by the upstream divertors, is to the first three second feet originating above their reservation.

TABLE 1

FULL NATURAL FLOW OF SAN LUIS REY RIVER
ORIGINATING BETWEEN
HENSHAW DAM AND GAGING STATION NEAR BONSALL

Area of Drainage Basin - 312 Square Miles

Season	Full natural flow, in acre-feet	Season	Full natural flow, in acre-feet	Season	Full natural flow, in acre-feet
1887-88	16,720	1903-04	6,380	1919-20	14,600
1888-89	35,550	1904-05	28,390	1920-21	4,510
1889-90	51,200	1905-06	65,790	1921-22	72,950
1890-91	47,750	1906-07	51,460	1922-23	18,890
1891-92	22,820	1907-08	18,310	1923-24	11,430
1892-93	25,210	1908-09	32,640	1924-25	6,120
1893-94	10,620	1909-10	31,040	1925-26	20,170
1894-95	100,000	1910-11	23,090	1926-27	82,490
1895-96	7,180	1911-12	9,320	1927-28	10,280
1896-97	19,380	1912-13	5,540	1928-29	1[illegible],580
1897-98	5,850	1913-14	24,840	1929-30	15,[illegible]10
1898-99	4,790	1914-15	88,250	1930-31	[illegible]
1899-00	4,520	1915-16	172,660	1931-32	5[illegible]
1900-01	12,750	1916-17	28,570	1932-33	12,7[illegible]0
1901-02	8,500	1917-18	19,060	1933-34	[illegible],910
1902-03	11,680	1918-19	10,290	1934-35	14,870

48-year (1887-1935) mean seasonal full natural runoff - [illegible]

In addition to its rights to water from above Henshaw Dam, the Escondido Mutual Water Company also may divert the full capacity of its canal, 70 second feet, when available, from the water originating between Henshaw Dam and the Escondido Intake.

Based on the irrigated areas found in the 1934-35 census and a consumptive use of 1.5 acre-feet per acre, private diversions from the river above the head of the proposed Bonsall reservoir probably amount to about 4,000 acre-feet per season. This estimate includes the lands irrigated by the Rincon Indians under their 3 second-feet right.

The releases from Henshaw to the Rincon Indians and the diversions by the Escondido Mutual Water Company are dependent on the surface runoff of the river and vary therewith. Practically all the diversions by private irrigators, however, are made by pumping from the river sands and gravels and consequently may draw on the storage therein during dry seasons.

In estimating the probable yield from a reservoir at Bonsall under present conditions all these factors must be considered. Consequently, the full natural flows presented in Table 1 have been adjusted to conform to these conditions. The adjustments for the Rincon releases and Escondido diversions were based on the available records of daily flows at the Henshaw dam site. The adjustments for diversions by private irrigators were based on a full diversion of 4,000 acre-feet every season. The adjusted flows at the gaging station near Bonsall are presented in Table 2, "Estimated Run Off of San Luis Rey River near Bonsall". These values represent the flows which would have occured had the present upstream diversions been made during the period for which values are presented. Any additional development increasing upstream diversions from the river will decrease the amounts available for use downstream.

TABLE 2

ESTIMATED RUNOFF OF SAN LUIS REY RIVER
at
BONSALL DAM SITE

Had present diversions been made in the past.

Area of drainage basin - 312 square miles

Month	Runoff, in acre-feet						
	1887-88	1888-89	1889-90	1890-91	1891-92	1892-93	1893-94
Oct.	30	0	0	0	0	0	0
Nov.	390	0	240	0	190	20	0
Dec.	2,320	1,090	25,170	0	590	420	1,730
Jan.	3,390	2,270	9,000	280	680	1,330	1,050
Feb.	2,820	2,580	6,730	28,430	5,510	1,170	2,550
Mar.	4,370	14,980	2,300	6,400	2,570	16,440	1,620
Apr.	370	4,760	490	2,370	3,940	2,060	460
May	0	1,140	0	990	3,360	60	0
Jun.	0	470	0	420	830	0	0
Jul.	0	50	0	0	80	0	0
Aug.	0	0	0	0	0	0	0
Sep.	0	0	0	0	0	0	0
Total	13,690	27,340	43,930	38,890	17,750	21,500	7,410
Month	1894-95	1895-96	1896-97	1897-98	1898-99	1899-00	1900-01
Oct.	0	0	0	0	0	0	0
Nov.	0	0	0	0	0	0	0
Dec.	2,420	0	0	0	0	0	0
Jan.	68,430	2,010	0	0	0	0	0
Feb.	8,790	840	4,200	1,600	0	0	6,180
Mar.	5,560	2,000	9,270	1,090	570	0	1,240
Apr.	2,720	170	730	230	770	770	730
May	280	0	0	0	10	780	370
Jun.	60	0	0	0	0	0	0
Jul.	0	0	0	0	0	0	0
Aug.	0	0	0	0	0	0	0
Sep.	0	0					
Total	88,260	5,020	14,200	2,920	1,350	1,550	8,520

TABLE 2
(Continued)

Month	Runoff, in acre-feet						
Month	1901-02	1902-03	1903-04	1904-05	1905-06	1906-07	1907-08
Oct.	0	0	0	0	0	0	0
Nov.	0	0	0	0	0	100	300
Dec.	0	0	0	0	390	2,650	720
Jan.	0	0	0	0	650	15,530	2,160
Feb.	70	330	0	4,[illegible]00	1,000	4,320	6,11[illegible]
Mar.	4,420	2,790	300	12,310	38,920	10,570	2,3[illegible]
Apr.	1,370	3,930	1,710	2,030	6,670	4,520	790
May	70	400	470	2,730	4,330	1,610	270
Jun.	0	0	190	520	1,560	430	0
Jul.	0	0	0	0	300	0	0
Aug.	0	0	0	0	50	0	0
Sep.	0	0	0	0	[illegible]	0	0
Total	5,630	7,450	2,670	22,390	56,120	43,330	13,750
Month	1908-09	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
Oct.	0	0	0	0	0	0	0
Nov.	0	0	210	0	0	0	0
Dec.	0	3,650	720	0	[illegible]0	0	0
Jan.	6,790	15,550	1,840	0	0	960	12,[illegible]70
Feb.	10,910	2,100	6,140	50	650	9,350	35,310
Mar.	4,550	2,450	6,570	2,970	1,740	5,500	10,5[illegible]
Apr.	2,300	1,550	2,360	1,070	790	1,700	3,900
May	700	100	160	2,440	0	1,570	9,[illegible]
Jun.	0	0	0	0	0	30	3,100
Jul.	0	0	0	0	0	0	700
Aug.	0	0	0	0	0	0	0
Sep.	0	0	0	0	0	0	0
Total	25,750	25,460	1[illegible],020	6,530	3,1[illegible]	19,710	76,120
Month	1915-16	1916-17	1917-18	1918-19	1919-20	1920-21	1921-22
Oct.	0	1,370	0	0	0	0	[illegible]
Nov.	0	1,320	390	1,290	[illegible]	0	0
Dec.	910	1,370	1,130	1,990	0	0	15,310
Jan.	131,210	4,250	1,6[illegible]0	1,300	1,160	0	8,7[illegible]0
Feb.	14,540	6,750	590	1,650	1,740	300	6,[illegible]
Mar.	6,990	2,510	9,310	1,270	1,1[illegible]0	560	15,300
Apr.	2,510	1,150	670	660	2,920	640	7,[illegible]
May	1,240	1,600	670	130	2,390	240	1,7[illegible]
Jun.	1,350	1,100	310	0	10	0	1,1[illegible]
Jul.	1,130	140	0	0	0	0	320
Aug.	590	0	0	0	0	0	[illegible]
Sep.	500	0	0	0	0	0	[illegible]
Total	160,970	21,940	15,250	8,340	9,400	2,240	56,530

TABLE 2
(Continued)

Month	Runoff, in acre-feet						
	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29
Oct.	0	0	0	0	0	0	0
Nov.	520	[illegible]0	0	0	0	0	0
Dec.	3,120	1,350	1,050	880	210	640	0
Jan.	2,180	1,340	1,090	910	780	1,640	650
Feb.	3,980	710	730	1,500	70,450	2,510	1,620
Mar.	2,240	2,320	660	870	2,650	1,350	2,010
Apr.	2,030	2,140	620	11,350	1,130	590	2,100
May	450	350	0	470	390	370	350
June	60	10	0	80	70	0	0
July	0	0	0	0	0	0	0
Aug.	0	0	0	0	0	0	0
Sep.	0	0	0	0	0	0	0
Total	14,580	8,520	4,150	16,060	75,680	7,100	7,230
Month	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	Mean
Oct.	0	0	0	0	0	0	
Nov.	0	0	0	0	0	0	
Dec.	0	0	2,420	1,030	430	30	
Jan.	1,460	1,230	1,980	2,790	750	2,720	
Feb.	1,090	2,050	33,990	2,010	940	4,070	
Mar.	2,210	640	5,750	1,250	760	1,860	
Apr.	880	380	1,840	920	320	1,110	
May	4,860	230	830	1,250	160	320	
Jun.	390	30	290	160	0	0	
Jul.	30	0	0	0	0	10	
Aug.	140	0	0	0	0	60	
Sep.	0	0	0	0	0	0	
Total	10,930	4,610	47,100	9,410	3,410	10,190	13,170

Flood Flows

An analysis of the probable flood flows on San Diego County streams was presented in Bulletin No. 48. This analysis included the San Luis Rey River and indicated probable flood flows as listed in Table 3, "Probable Size and Frequency of Flood Flows on the San Luis Rey River at Oceanside."

TABLE 3

PROBABLE SIZE AND FREQUENCY OF FLOOD FLOWS
ON THE
SAN LUIS REY RIVER AT OCEANSIDE
FROM THE
DRAINAGE BASIN BELOW HENSHAW DAM.

Area of drainage basin - 359 square miles

Frequency with which floods may be expected to occur	Mean daily flow, in second feet	Crest flow, in second-feet
Once in 25 years	17,000	25,600
Once in 50 years	24,900	41,800
Once in 100 years	31,500	58,000
Once in 250 years	47,900	80,500

CHAPTER III

CONSERVATION AND FLOOD CONTROL

Present Development

The San Luis Rey River in its course from Rincon to the ocean passes through a series of basins which have been filled with sand and gravel to depths ranging from 50 to over 100 feet. These basins all provide underground storage which may be utilized to supplement the natural flow of the stream during dry periods. There are three major basins: the Pala Basin from Rincon to Monserate Narrows; the Bonsall Basin from Monserate Narrows to Bonsall Narrows and the Mission Basin from Bonsall Narrows to Oceanside. An independent study of the available underground storage in these basins was not made in this investigation. However, the United States Geological Survey made such a study * in 1914 and 1915 and a reconnaisance survey was made by the Division of Water Resources during the San Diego County Investigation reported in Bulletin No. 48. From these studies it seems probable that the underground storage in the Pala Basin is at least 20,000 acre-feet, in the Bonsall Basin 21,000 acre-feet, and in the Mission Basin 12,300 acre-feet.

The 1934-35 crop survey published in Bulletin No. 48 shows that at that time 1360 acres were irrigated from the Pala Basin. With a consumptive use of 1.5 acre-feet per acre the present draft on the Pala Basin would be 2,040 acre-feet per season. 1,233 acres of orchard, vineyard, truck crops and alfalfa and 1,580 acres of field crops were irrigated in the Bonsall Basin. With consumptive uses of 1.6 acre-feet for the former and 0.5 acre-feet per acre for the latter, the seasonal draft on the Bonsall Basin would be 2,763 acre-feet. 1,499 acres were irrigated from the Mission Basin. With a consumptive use of 1.6 acre-feet per acre the irrigation

*1. United States Geological Survey, Water-Supply Paper 446, Geology and Ground waters of the Western Part of San Diego County, California by Arthur J. Ellis and Charles H. Lee, 1919.

draft at present would be 2400 acre feet per season. There are also the drafts of the City of Oceanside and the Carlsbad Mutual Water Company which in their maximum years have amounted to 1200 and 2300 acre-feet respectively. The present seasonal draft on the Mission Basin therefore would be about 5,900 acre-feet. This draft, 5,900 acre-feet, from the Mission Basin, is about the safe yield from the 12,300 acre-feet of storage in that basin. The total flow past Bonsall during the dry period, 1897-1900, is given in Table 2 as 5,820 acre-feet. The corresponding flow from local drainage is given in Bulletin No. 48 as 1,200 acre-feet. Assuming the basin full at the start of the period the total water available would have been 19,320 acre-feet. Under present conditions the draft during the three year period would have been 17,700 acre-feet, leaving a surplus of only 1,620 acre-feet to flow into the ocean and prevent salt water intrusion in the gravel beds.

The total underground storage in the three basins is estimated as about 53,300 acre-feet. During the dry period 1895-1904 the total runoff at Bonsall is given in Table 2 as 49,300 acre-feet. The runoff from the area below Bonsall is given in Bulletin No. 48 as 7,400 acre-feet. Under present conditions, assuming the basins full at the start of the period it is estimated that an average seasonal flow of 12,200 acre-feet would have been available. The mean seasonal flow at the Bonsall dam site as shown in Table 2, based on the 48 year period 1887-1935 is 23,170 acre-feet. Therefore, it is apparent that full conservation of the flood flows will require the provision of additional storage space.

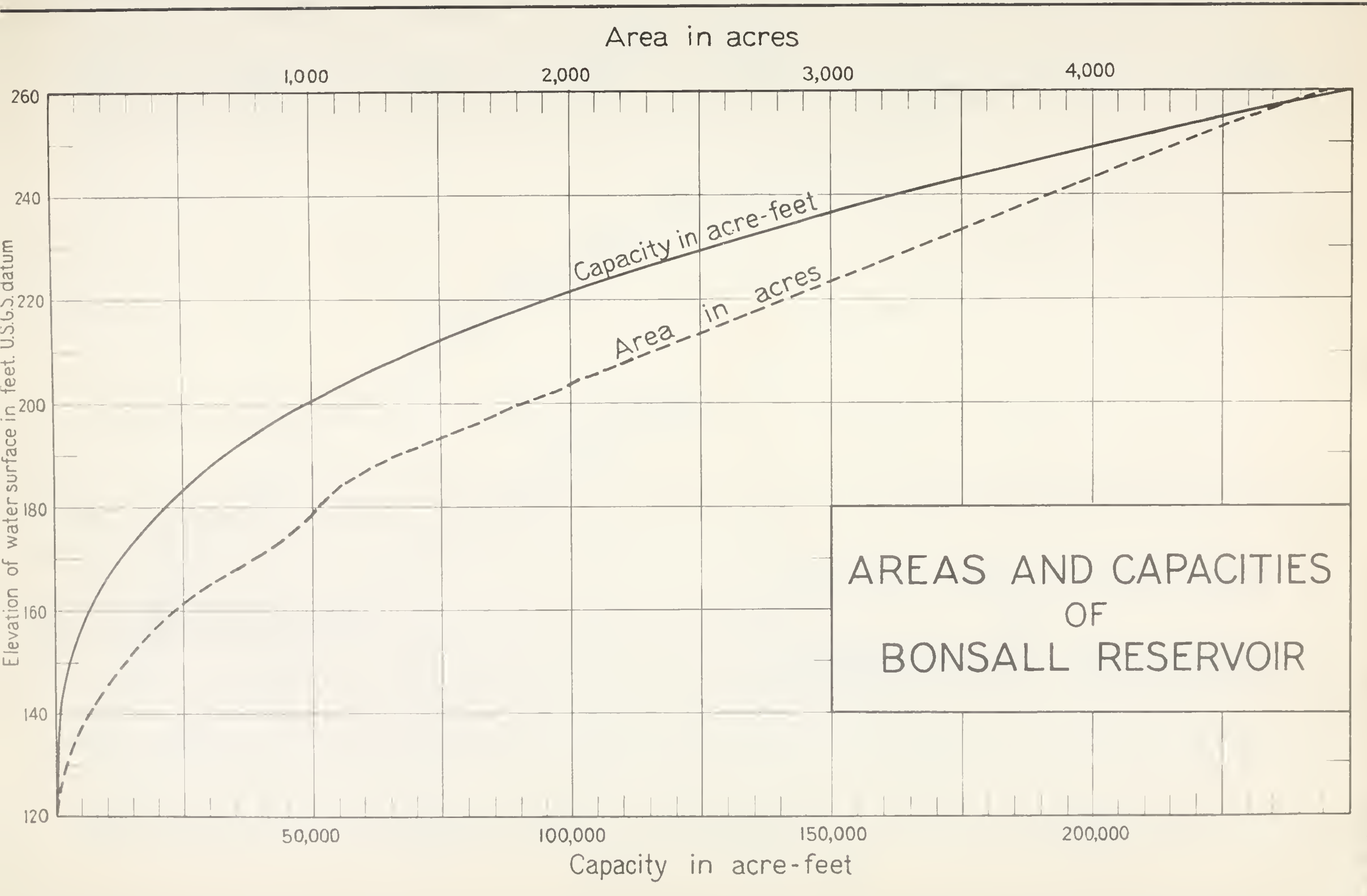
Under present conditions each user pumps from the underground basins whenever he wishes and locates his pumps where ever it may be most convenient. At present, replenishment is from the uncontrolled flow of the stream and

even in dry years much water is wasted into the ocean. The full utilization of the underground storage will require adequate spreading works to obtain the maximum possible recharge from the flow of the stream and an orderly distribution of pumping plants so that all portions of the underground reservoir may be used.

Reservoir Sites

The analyses presented in Bulletin No. 48, Table 20, indicated that approximately 183,000 acre-feet of storage capacity would be needed to conserve the flow of the San Luis Rey River below Henshaw Dam. A reconnaissance of the drainage basin showed that this amount of storage could probably be most easily obtained by reservoirs either in the Bonsall basin, above a dam built near the present State highway crossing, or in the Pala Basin above a dam built in the Monserate Narrows above the San Luis Rey Ranch. Other dam and reservoir sites were found on Pauma Creek and on Moosa Canyon.

This investigation provided for surveys of both the Bonsall and Monserate Reservoirs. These surveys were made by plane table at a scale of one inch equal to 400 feet with 10 foot contours being drawn in. The resultant topographical maps are shown in Appendix A, "Topography of Bonsall Damsite and Reservoir" and in Appendix B, "Topography of Monserate Damsite and Reservoir". Area and capacity curves for the Bonsall reservoir are shown on Plate II, "Areas and Capacities of Bonsall Reservoir" and for the Monserate Reservoir on Plate III, "Areas and Capacities of Monserate Reservoir". The areas and capacities at 10 foot intervals for each reservoir are listed in Table 4, "Areas and Capacities of Bonsall Reservoir" and Table 5, "Areas and Capacities of Monserate Reservoir". A comparison of the data in Tables 4 and 5 is presented in Table 6, "Comparison of Flooded Areas and Capacities of Bonsall and Monserate Reservoirs". This comparison shows that any given amount of storage in excess of 48,000 acre-feet may be obtained at Bonsall with a lower dam than would be required for the same amount of storage at Monserate.


Area in acres
1,000
2,000
3,000
4,000
260
240
220
200
180
160
140
120
Elevation of water surface in feet. U.S.G.S. datum
Capacity in acre-feet
Area in acres
AREAS AND CAPACITIES
OF
BONSALL RESERVOIR
50,000
100,000
150,000
200,000
Capacity in acre-feet

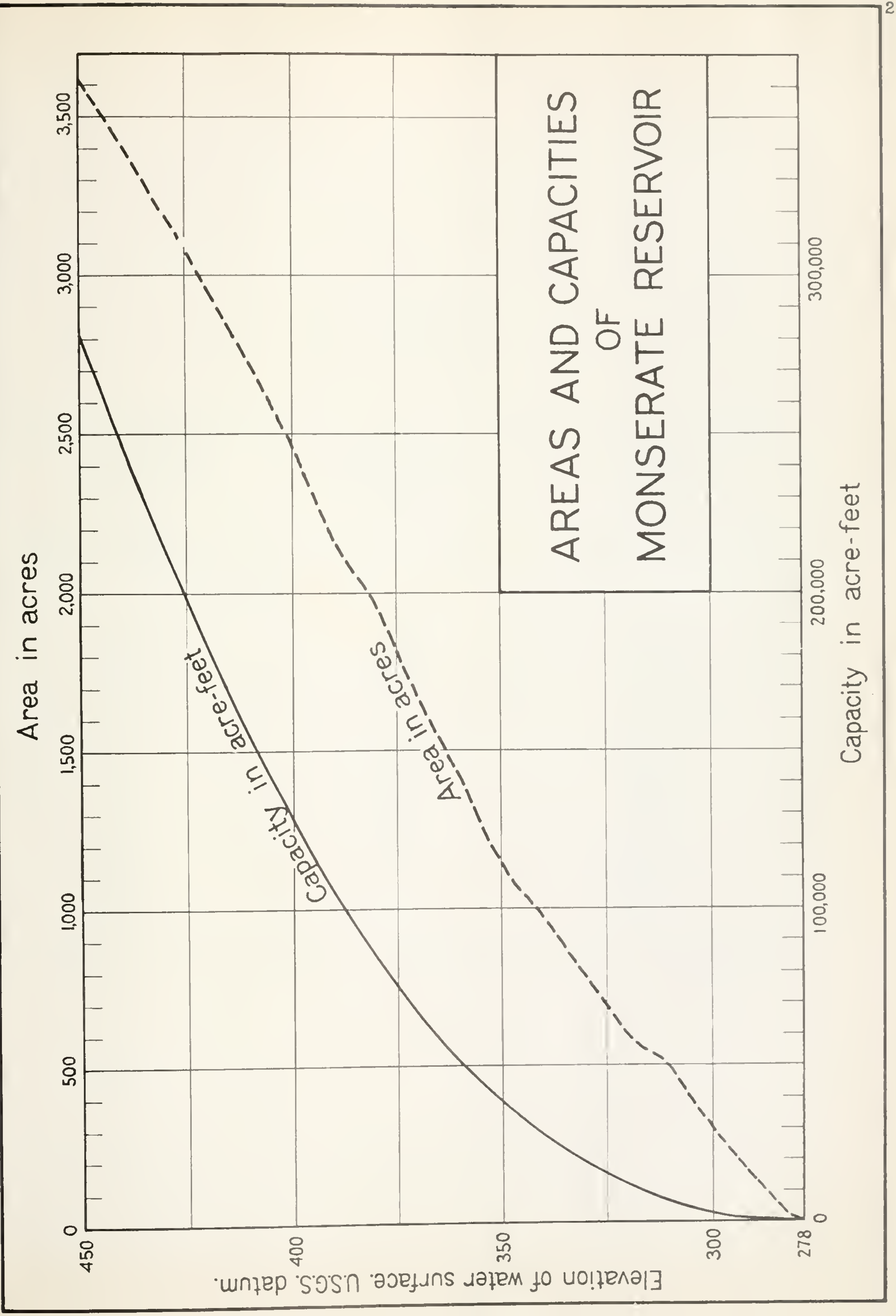

AREAS AND CAPACITIES
OF
MONSERATE RESERVOIR
Area in acres
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Capacity in acre-feet
0
100,000
200,000
300,000
Elevation of water surface. U.S.G.S. datum.
450
400
350
300
278
Capacity in acre-feet
Area in acres

TABLE 4

AREAS AND CAPACITIES
OF
BONSALL RESERVOIR

Elevation of water surface, in feet U.S.G.S. Datum	Area of water surface, in acres	Capacity of reservoir, in acre-feet
120	0	0
130	35	131
140	133	923
150	278	2,951
160	458	6,592
170	771	12,612
180	1,026	21,7[illegible]
190	1,341	33,340
200	1,830	49,170
210	2,329	69,957
220	2,836	95,764
230	3,342	126,691
240	3,840	162,605
250	4,346	203,515
260	4,879	249,636

TABLE 5

AREAS AND CAPACITIES
OF
MONSERATE RESERVOIR

Elevation of water surface, in feet U.S.G.S. Datum	Area of water surface, in acres	Capacity of reservoir, in acre-feet.
278	0	0
280	6	6
290	144	737
300	305	2,960
310	491	6,919
320	603	12,387
330	735	19,294
340	972	28,108
350	1,139	38,630
360	1,418	51,379
370	1,676	66,365
380	1,966	85,069
390	2,179	105,793
400	2,473	129,058
410	2,723	155,046
420	2,962	183,433
430	3,192	211,263
440	3,414	247,294
450	3,621	282,437

TABLE 6

COMPARISON OF FLOODED AREAS AND CAPACITIES
OF
BONSALL AND MONSERATE RESERVOIRS

Depth of water in feet	Flooded area, in acres		Capacity, in acre-feet	
	Bonsall reservoir	Monserate reservoir	Bonsall reservoir	Monserate reservoir
10	35	114	131	479
20	133	270	923	2,385
30	278	452	2,951	5,976
40	458	573	6,592	11,212
50	771	746	12,612	17,763
60	1,026	933	21,708	26,198
70	1,341	1,099	33,34[illegible]	36,393
80	1,830	1,361	49,170	4[illegible],600
90	2,329	1,624	69,957	63,566
100	2,838	1,910	95,754	81,194
110	3,342	2,129	126,691	101,485
120	3,840	2,413	162,605	124,166
130	4,346	2,674	203,515	149,652
140	4,879	2,915	249,635	177,605

BONSALL DAM AND RESERVOIR SITE
ON
SAN LUIS REY RIVER

View upstream showing dam site between hills in left and right foreground and reservoir basin which extends past hills in right background of picture.

MONSERATE RESERVOIR BASIN
ON
SAN LUIS REY RIVER

View across lower portion of reservoir basin from right abutment. The main canyon extends upstream to the left of the picture.

Evaporation

In determining the probable safe yield which may be obtained by storage of excess water in surface reservoirs one of the major factors is the probable loss by evaporation from the water surface. This subject was discussed quite fully in Bulletin 48 and consequently will not be re-discussed here. In estimating the evaporation from the water surface of the Bonsall reservoir, the same rate of gross evaporation, 60 inches per season, was used as was used in Bulletin 48 for the Mission Gorge Reservoir on the San Diego River. Both reservoirs lie in much the same position in relation to the ocean and the mountains. The rainfall was based on analyses of the records at Oceanside, Vista, and Fallbrook.

Yields

Analyses of the probable safe yields which might have been obtained from the San Luis Rey River during the 48-year period 1887-1935 under present conditions of upstream development by the construction of reservoirs in the Bonsall basin storing 49,170, 95,780, and 162,610 acre-feet have been made. These analyses were made on a monthly basis by the methods described in Bulletin No. 48. The results of these studies are shown in Table 7, "Yields of Bonsall Reservoir on San Luis Rey River".

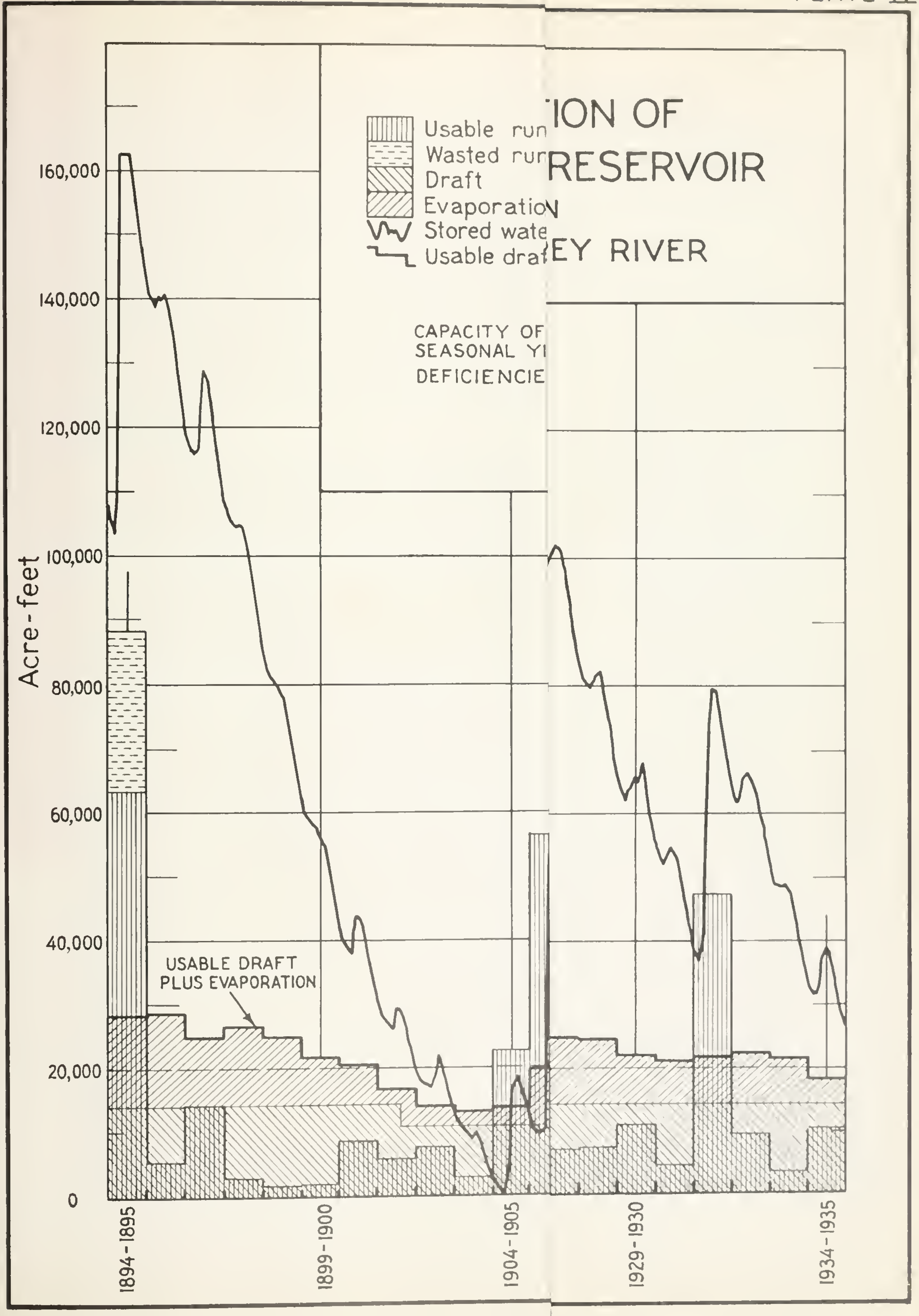
TABLE 7

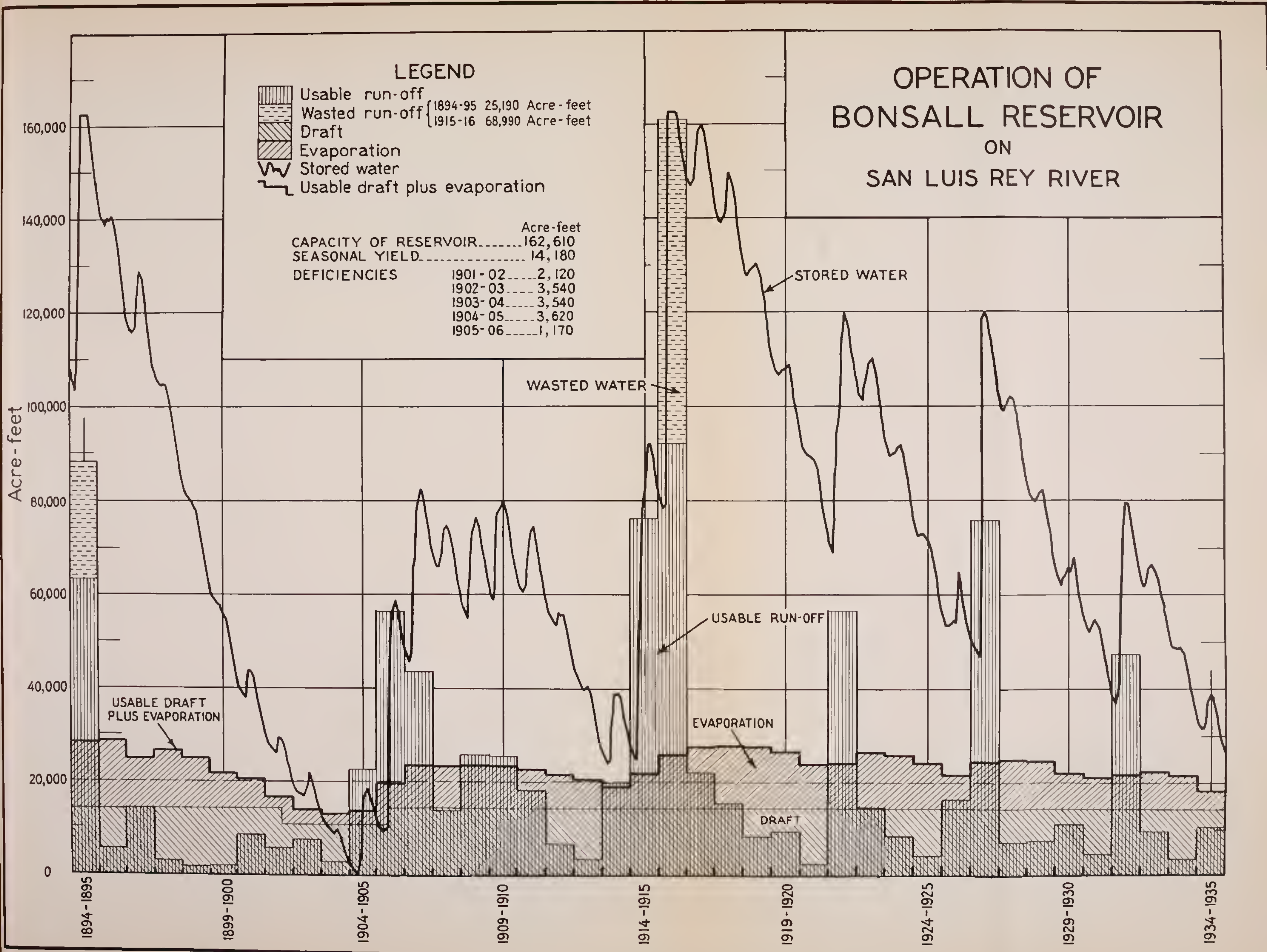
YIELDS OF BONSALL RESERVOIR
ON
SAN LUIS REY RIVER

Capacity of Reservoir, in acre-feet	Safe Yield, in acre-feet	Yield with 25% Deficiency in acre-feet
49,170	6,020	
95,780	8,530	
162,610	12,730	14,180

An analysis was also made of the yield which could be obtained from the 162,610 acre-foot reservoir by taking a deficiency of 25 per cent in the seasonal draft whenever the storage in the reservoir was less than 30,000 acre-feet on May 1st. The yield indicated by this analysis, also shown in Table 7, and the operation of the reservoir during the 41-year period, 1894-1935, is shown graphically on Plate IV, "Operation of Bonsall Reservoir on San Luis Rey River". Of the total inflow during the period analyzed, 941,650 acre-feet, only 94,180 acre-feet or 10.0 per cent, were wasted through the spillway; 361,500 acre-feet, 38.4 per cent, were lost by evaporation and 485,970 acre-feet, 51.6 per cent, were conserved for beneficial use.

At present the entire draft, 5,900 acre-feet, from the San Luis Rey River below the Bonsall dam is made by wells in the Mission basin. Should the Bonsall dam be constructed, the City of Oceanside and the Carlsbad Mutual Water Co. might connect their distribution systems directly to the reservoir thus utilizing the head provided to reduce their pumping lifts. Or the Bonsall reservoir might be used as an equalizing reservoir releasing water to replace that pumped from the Mission Basin. Under the latter method of operation water levels in the Mission Basin could be held comparatively low during the winter season, thus providing space for the conservation of the runoff from the area below the Bonsall dam. In Bulletin No. 48 this is estimated to amount to some 3,370 acre-feet per season on the average with a seasonal variation of from 0 to over 19,000 acre-feet. By utilizing the 12,300 acre-feet of space in the Mission Basin for the storage of this flow an additional yield of about 2,000 acre-feet could probably be obtained. The Mission basin would be filled from the Bonsall


Usable run
Wasted rur
Draft
Evaporatio
Stored wate
Usable draf
TION OF
RESERVOIR
EY RIVER
CAPACITY OF
SEASONAL YI
DEFICIENCIE
Acre-feet
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
USABLE DRAFT
PLUS EVAPORATION
1894-1895
1899-1900
1904-1905
1929-1930
1934-1935


OPERATION OF
BONSALL RESERVOIR
ON
SAN LUIS REY RIVER
LEGEND
Usable run-off
Wasted run-off
1894-95 25,190 Acre-feet
1915-16 68,990 Acre-feet
Draft
Evaporation
Stored water
Usable draft plus evaporation
Acre-feet
CAPACITY OF RESERVOIR 162,610
SEASONAL YIELD 14,180
DEFICIENCIES
1901-02 2,120
1902-03 3,540
1903-04 3,540
1904-05 3,620
1905-06 1,170
STORED WATER
WASTED WATER
USABLE RUN-OFF
EVAPORATION
DRAFT
USABLE DRAFT PLUS EVAPORATION
Acre-feet
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1894-1895
1899-1900
1904-1905
1909-1910
1914-1915
1919-1920
1924-1925
1929-1930
1934-1935

reservoir each spring after the winter runoff had occurred thus making some saving in evaporation losses.

Because of the lack of sufficient technically trained help, no further detailed analyses have been made. It is probable that an increase in yield could be shown by determining the savings in present transpiration and evaporation losses from the reservoir areas which would be flooded by the reservoir and from the surface areas of the underground basins if the water tables therein should be lowered.

Flood Control

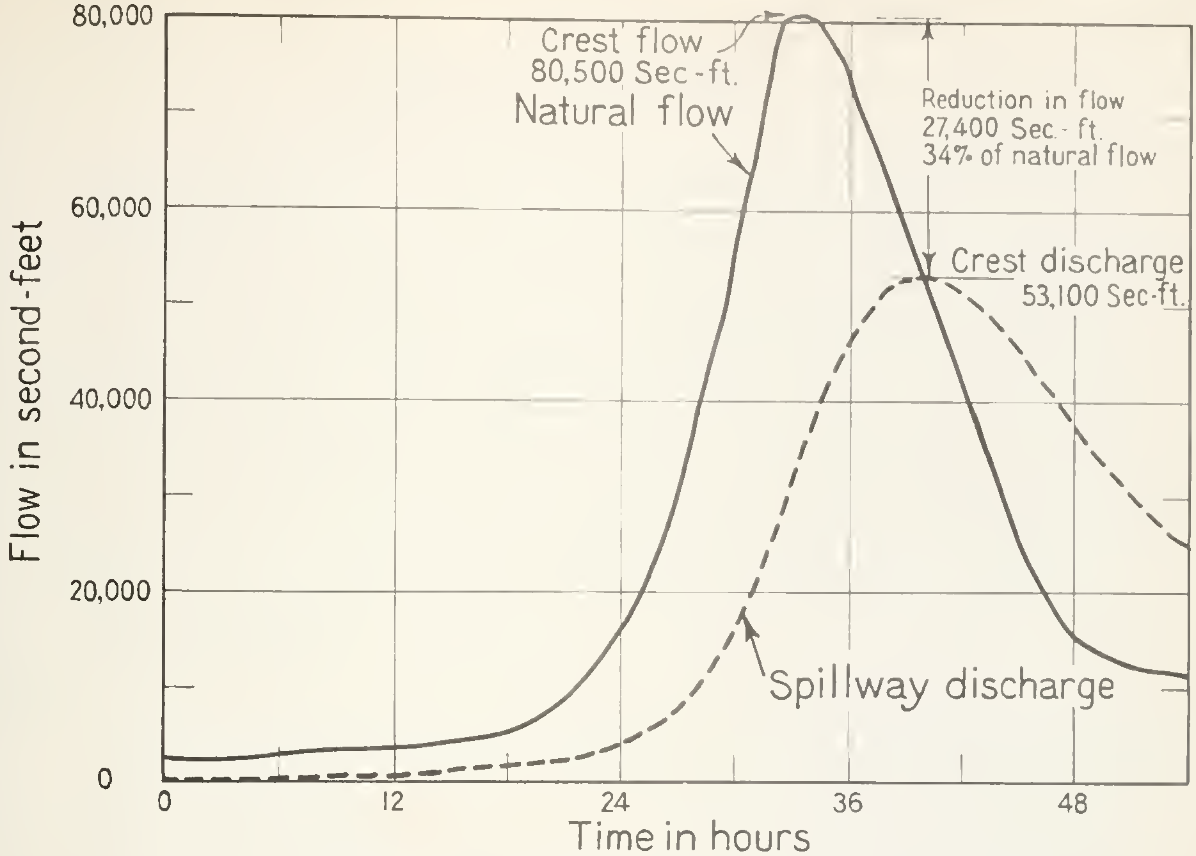
Should the 140 foot dam be built, the operation of the reservoir to yield 14,180 acre-feet seasonally would automatically store the waters of all but major floods. The operation studies show that spill past the dam would have occurred in only two seasons, 1894-95 and 1915-16, in the period from 1894-1935. In the first of these seasons only 25,000 acre-feet were spilled and in the second 69,000 acre-feet were spilled. The flood of January 27, 1916, the largest of which flow records are available, would have passed through the spillway with a maximum flow of only 16,900 second-feet, about thirty-seven per cent of the maximum flow which would have occurred under present conditions of upstream development. Assuming the reservoir filled prior to the occurrence of the flood the crest of the estimated once-in-250-year flood would be reduced more than one-third in passing through the spillway. The reductions in crest flow caused by the passage of these two floods through the spillway are shown graphically on Plate V, "Effect of Bonsall Reservoir on Flood Discharge".

reservoir each spring after the winter runoff had occurred thus making some saving in evaporation losses.

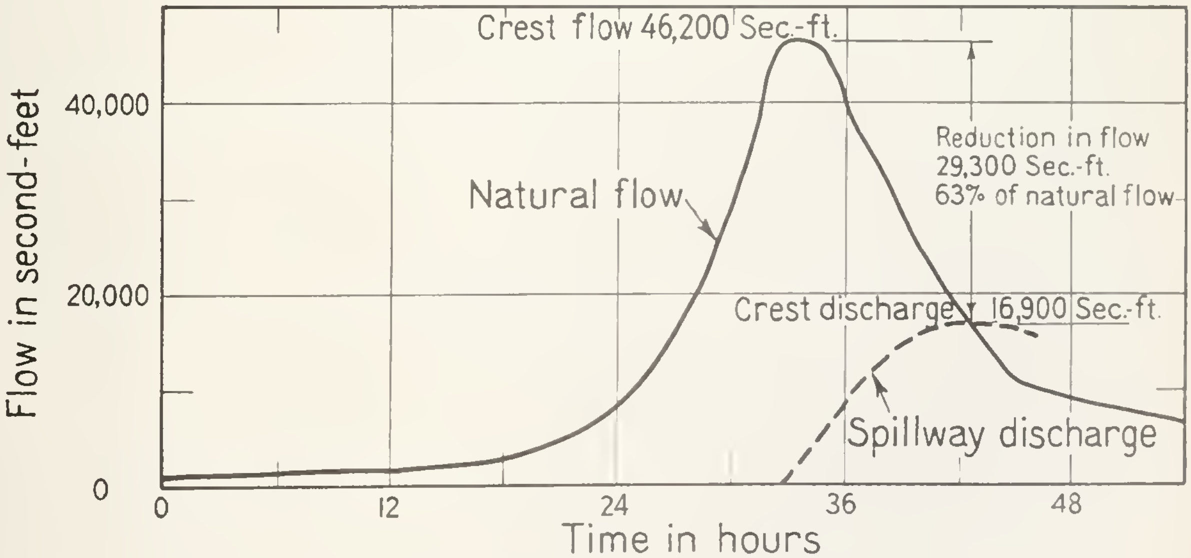
Because of the lack of sufficient technically trained help, no further detailed analyses have been made. It is probable that an increase in yield could be shown by determining the savings in present transpiration and evaporation losses from the reservoir areas which would be flooded by the reservoir and from the surface areas of the underground basins if the water tables therein should be lowered.

Flood Control

Should the 140 foot dam be built, the operation of the reservoir to yield 14,180 acre-feet seasonally would automatically store the waters of all but major floods. The operation studies show that spill past the dam would have occurred in only two seasons, 1894-95 and 1915-16, in the period from 1894-1935. In the first of these seasons only 25,000 acre-feet were spilled and in the second 69,000 acre-feet were spilled. The flood of January 27, 1916, the largest of which flow records are available, would have passed through the spillway with a maximum flow of only 16,900 second-feet, about thirty-seven per cent of the maximum flow which would have occurred under present conditions of upstream development. Assuming the reservoir filled prior to the occurrence of the flood the crest of the estimated once-in-250-year flood would be reduced more than one-third in passing through the spillway. The reductions in crest flow caused by the passage of these two floods through the spillway are shown graphically on Plate V, "Effect of Bonsall Reservoir on Flood Discharge".



ESTIMATED ONCE IN 250 YEAR FLOOD
Reservoir full at start of flood



FLOOD OF JANUARY 27, 1916
With deductions for present diversions,
Operated for conservation of 14,180 acre-feet per season

EFFECT OF BONSALL RESERVOIR ON FLOOD DISCHARGE

STORAGE 162,610 ACRE-FEET

CHAPTER IV

BONSALL DAM AND RESERVOIR

The Bonsall Reservoir site is located in Section 4 and 5, T 11 S, R 3 W; in Section 12, 14, 15, 18, 19, 20, 21, 26, 27, 28, 29, 30, 31, 32 and 33, T 10 S, R 3 W, S. B. B. and M.; and in the Monserate Grant. The main dam site is in the SW$\frac{1}{4}$ of Section 31 and an auxiliary dam is in the NW$\frac{1}{4}$ of the same section. Topographic surveys and maps of the dam sites have been made at a scale of one inch equals one hundred feet with a contour interval of five feet. These maps are shown in Appendix "A" Topography of Bonsall Dam Site and Reservoir.

Geology

A geologic study of the dam site was made during this investigation. In the course of this study about 1553 lineal feet of trenches 2.5 feet wide by from five to fifteen feet in depth and 8 test pits six by six by from 10 to 12 feet deep were dug; 298 lineal feet of three inch augur holes were bored in 13 holes; a six by six foot tunnel 30 feet long was dug in the right abutment and 4 twelve-inch wells were drilled in the river bed to depths of from 27 to 58 feet. A total of 177.5 feet of well were drilled. The locations of these various workings are shown on the topographic map of the dam sites in Appendix A. Profiles showing the classifications of the materials found are also shown in Appendix A.

The Bonsall dam site is located on the San Luis Rey River at a point where the stream has cut its channel through the northwestern end of a small range known as the San Marcos Mountains. Gopher Canyon which drains the northeasterly slopes of these mountains and enters the reservoir basin about one half mile upstream from the dam site is the only depression of any size between the dam site and Bonsall two miles upstream. Active faulting has not been recorded in this area but shocks from distant

faulting are often felt throughout northern San Diego County. The courses of Gopher Canyon and the smaller canyon opposite may have been determined by a local fault. Another may run down the left side of the river through the spillway site.

The San Marcos Range is granitic in character, quite worn down, and exhibits a rolling topography. There are a few rocky outcrops in the vicinity of the dam site but most of the area is covered with about a foot of soil and supports a vigorous growth of brush. Away from the steeper sides of the river canyon, the rolling hills along both sides of the river bank are cultivated. The granite is rather poor in quality and on the surface it often exhibits spheroidal weathering. In this type of weathering there is much disintegration around hard nodules of rock of varying size. The right side of the river in the vicinity of the dam site shows numerous weathered rock outcrops, and at the axis of the dam site there are some hard bouldery masses strewn along the hillsides. The left side of the river in the vicinity of the dam site shows but few hard rock outcrops along its upper portion, but there is quite a continuous outcrop of hard rock extending beyond the limits of the dam site below the elevation of the present highway.

Excavation

At the dam site the river bed is about nine hundred feet wide, a comparatively level bed of sand and, except for a [illegible] low water channel, overgrown with willows. The line of junction of hillside and river bed is well marked both by topography and by vegetal cover. [illegible] wells were drilled in the river bed. The logs of these wells are given [illegible], "Logs of Wells Drilled at Bonsall Dam Site". These logs indicate that hard granite should be encountered at an elevation of about 70 feet above sea level, about 50 feet below the low point in the present river channel and that the old channel is probably gently rounded rather than a sharp "V" shaped [illegible].

TABLE NO. 8

LOGS OF WELLS DRILLED AT BONSALL DAM SITE

Well No. 1		Well No. 2		Well No. 3		Well No. 4	
Depth, in feet		Depth, in feet		Depth, in feet		Depth, in feet	
0.	Elev. 124	0.	Elev. 120	0.	Elev. 124	0.	Elev. 126
	River sand		River sand		River sand		River sand
20.6		31.0		40.		21.	
	Water gravel		Water gravel		River sand &		Small gravel
23.2					Cobbles		
	Decomposed granite	50.5		54.6		23.5	
			Hard granite		Decomposed granite		Clay & granite
23.8		55.8		55.6		27.	
	Boulders				Hard granite		Decomposed granite
26.4				58.3		35.5	
	Hard granite						Hard granite
27.4							

The estimated bed rock line is shown in the profile in Appendix [illegible]. The materials of the valley fill are largely river sands and gravels which could be easily excavated.

The right abutment of the dam is located on a small hill rising to an elevation of 290 feet above sea level which is slightly higher than the rest of the low ridge which forms the right bank of the reservoir. The topography is rounded and the slopes are even with no sudden breaks. The surface shows numerous granite boulders, the product of spheroidal weathering. The trenches, test pits, and tunnel which were dug in this abutment show an average of about one foot of soil rapidly changing to a coarse disintegrated granite in place. The disintegration is rather deep. Spheroidal boulders in place were encountered in the right abutment tunnel but very little hard rock was found in the right abutment exploratory trench. The disintegrated bed rock, however, consolidates quite rapidly and at depths of about four feet the original structure of the rock is quite apparent. This hill provides a satisfactory abutment for an earth dam. The top foot of soil which supports a moderately heavy growth of brush should be stripped and wasted. Under the impervious section of the dam excavation should extend through an additional three feet. The material which will be excavated is suitable for use in the down stream section of the dam and may be suitable for use in the impervious section.

The left abutment is a small rounded hill standing out alone as a topographic feature. It is uniformly rounded on all sides with no sudden breaks in the slopes. The foot of this hill shows an almost continuous outcropping of hard granite which appears in the left bank of the river bed upstream from the dam as a gently sloping shelf covered with a shallow layer of soil. The upper part of the hill is deeply weathered and shows no outcrops or boulders on the surface. Bedrock is exposed along the entire length

of the present highway cut on the left abutment. Most of the bed rock is soft and decomposed but there is one zone of hard dark colored granite crossing the road cut which seems to line up with the hard rock found in the exploratory tunnel on the right abutment of the dam site. On the left abutment stripping should be carried to a depth of one foot and the excavation under the impervious section of the dam should be carried about three feet deeper.

The spillway for the dam may pass through the gap which separates this hill from the main body of the range. This pass crests at an elevation of about 225 feet above sea level. Test Pit No. 7 which was dug in the low portion of the gap showed a soil depth of about eight feet. Trench No. 5, however, showed that a relatively narrow depression in the bed rock separated the left abutment knoll from the main hills. At this point the soil depth reached a maximum of 16 feet. The alluvium in this depression contained some water worn material indicating that an old stream channel may have been eroded along this possible fault line which was previously suggested as having passed through the spillway site. At the bottom of the trench the rock was fairly hard and seemed to be continuous. From the evidence exposed in the trench, it is believed that a satisfactory foundation for an Ogee spillway will be found at a depth of from ten to fifteen feet below the present surface.

For a distance of approximately three-quarters of a mile upstream from the main dam site the right bank of the reservoir is formed by a low chain of hills varying in elevation from 250 to 275 feet above sea level. Opposite Gopher Canyon this low range turns away from the river and forms the western bank of a small canyon, the course of which may have been determined by the local fault previously suggested. Along this canyon the ridge crops in two places to elevations of about 210 feet above sea level. Any reservoir which takes advantage of the full height of the abutments at the

main dam site will require auxiliary dams along this ridge. The ridge is uniformly rounded and relatively steep on the river side but slopes gently away on the side opposite the river. The crest and gently rolling slopes have been cleared and a large part of the cleared area is piped for irrigation.

The character of the materials in the ridge and on the abutments of the auxiliary dam sites has been explored with 13 augur holes and one test pit. The locations of these borings, shown on the topographic map of the dam site, and a profile of the ridge showing the materials encountered in the augur borings and Test Pit No. 3 are shown in Appendix A. The soil depths along the crest of the ridge average from three to five feet and overlay a deposition of residual material comprised mostly of micaceous sand approximately ten feet in depth. Decomposed granite is encountered at depths of from fifteen to twenty-five feet. Stripping for the auxiliary dams along this ridge should average about two feet in depth and the excavation under the impervious sections of the fills should average ten feet deeper. The excavated materials, however, can be reworked and embodied in the pervious portions of the fills.

One of the proposed auxiliary dams cuts across a depression to meet the hills on the north rather than to meander up the long extension of the ridge. The bed of this depression is about 200 feet wide and is filled with deposits of water worn gravel, sand, and silt. Stripping across the bottom should reach two feet below the surface, and decomposed granite should be found about twenty feet deeper. Along the sides of the depression bed rock should be encountered at a much shallower depth.

Under all dams a concrete cutoff along the impervious portion of the fill should extend below the excavation to sound granite or into material that will safely resist underground percolation.

Materials for Construction

The necessary excavation in the bed of the San Luis Rey River will provide sufficient sand and gravel of suitable quality for concrete.

Sufficient material with which to construct the impervious sections of the main earth fill and the auxiliary structures was found about one-half mile upstream in the SE$\frac{1}{4}$ of the NW$\frac{1}{4}$ of Section 31 where the erosion of small channels to depths of ten to fifteen feet has exposed a deposit of red clay alluvium which is believed to be satisfactory.

The pervious downstream portion of the fill may be made from the excavations in the river bed and the spillway channel and from the disintegrated granite of the surrounding hills.

Dam and Reservoir

It is probable that either an earth fill, rock fill or concrete dam could be built at this point. However since there are no extensive outcrops of rock close by which would be suitable for a rock fill and since a concrete structure would require extensive excavation in both abutments, an earth fill type of dam has been designed for this structure.

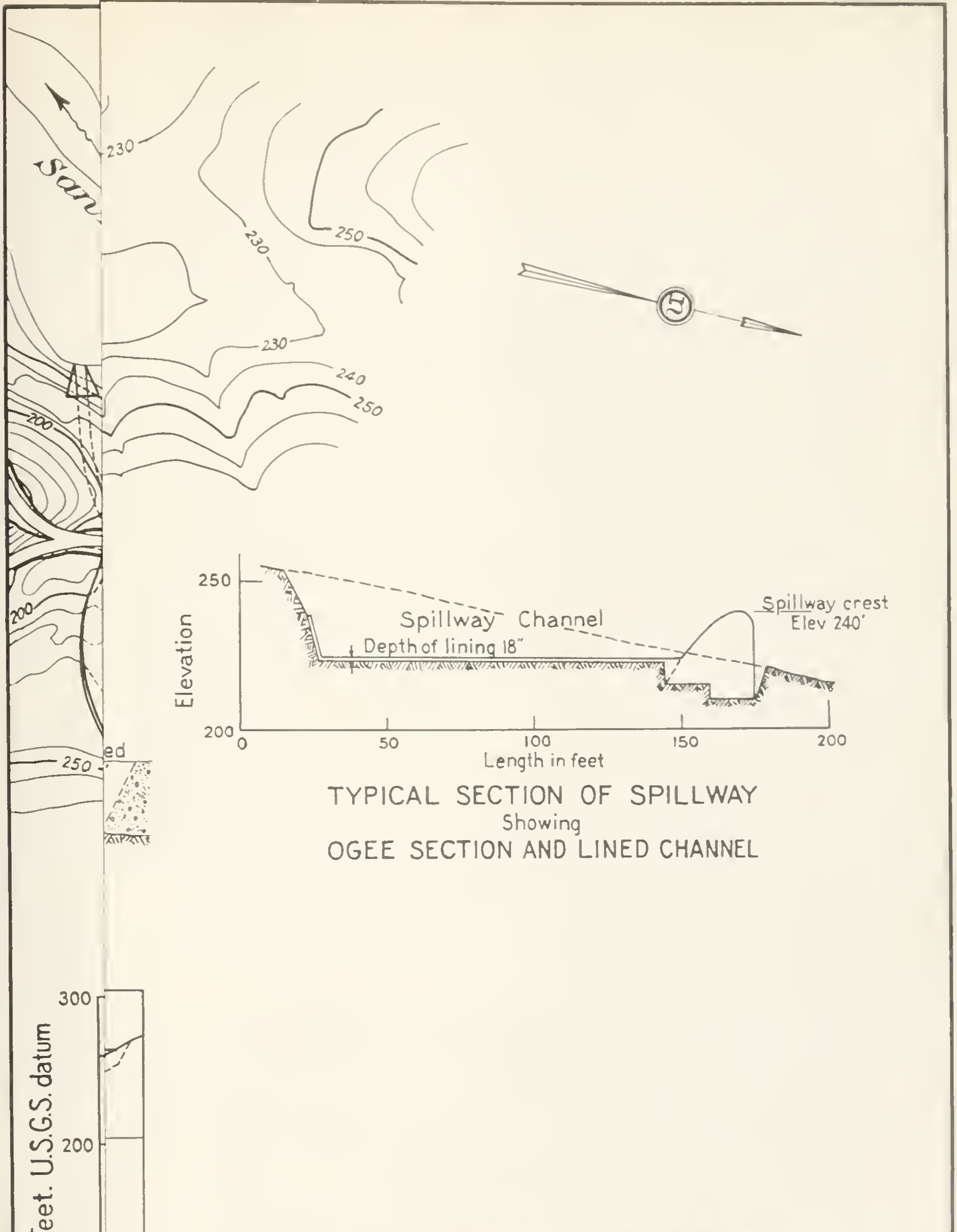
Estimates have been made of the costs of reservoirs with rolled earth fill dams with crests at elevations 220 and 260 feet above sea level. In making these estimates both main dams were designed with an impervious section with a crest width of ten feet and slopes of 2.5:1 upstream and 1:1 downstream, faced with a concrete paving 12 inches thick, normal to the slope. The downstream pervious section was given a crest width of 40 feet and a downstream slope of 2.5:1 to a point 50 feet below the crest where it was flattened to 3:1. The impervious section was extended to bed rock but the pervious section ended at the stripping line. A concrete cutoff 2.5 feet wide was placed at the upstream toe and extended 15 feet below the line of excavation. The spillway consisted of a concrete Ogee section without gates and with crest 20 feet below

the top of the dam. It was [illegible] feet long and would discharge [illegible],5[illegible] cubic feet per second, the crest flow of a once-in-25[illegible]-year flood, with the water surface 5.5 feet below the crest of the main dam. The channel passing through the gap between the left abutment and the main range of hills was concrete lined throughout. During the construction of the dam the stream flow would be by-passed through a 3[illegible]' tunnel under the left abutment. This tunnel would be concrete lined throughout and after construction would be plugged at the upper end and used as a conduit for the outlet pipe. Water would enter the pipe through a circular concrete tower with gate valves controlled from a gate house on the top of the tower. The flow through the outlet pipe would be controlled by a needle valve at the downstream end of the tunnel and an emergency slide gate would be placed immediately below the tunnel plug.

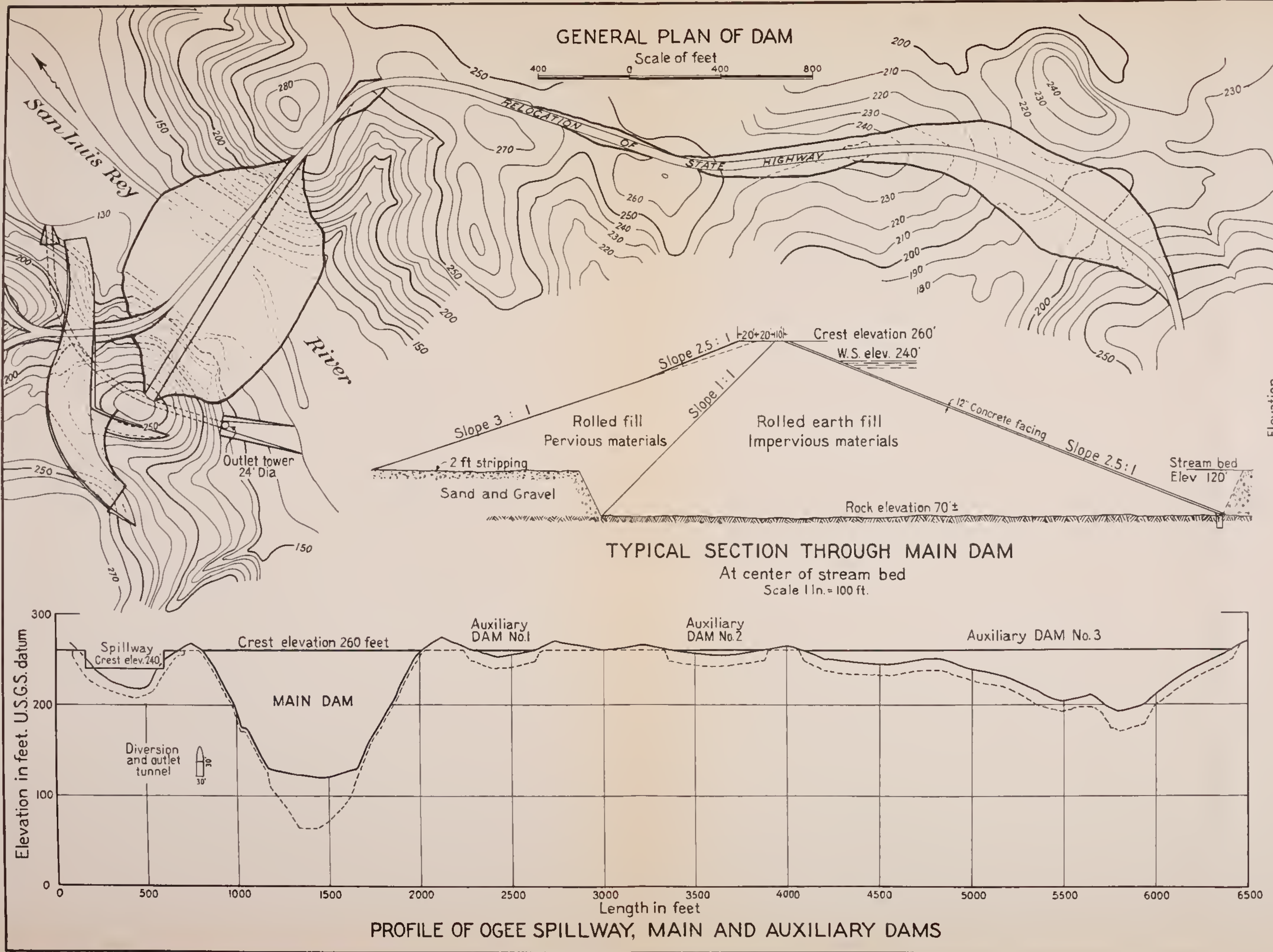
The auxiliary dams were designed similarly to the main dam except that the total crest widths were only [illegible] feet.

The valuation of the reservoir lands, all in private ownership, which it would be necessary to acquire has been based on the 1[illegible]36 tax rolls of San Diego County. The assessed values are said to be about fifty per cent of the true value. In estimating the cost of acquiring these lands, however, a figure three times the assessed valuation has been used.

As previously stated estimates of cost were made for reservoirs created by dams with crests at elevations 22[illegible] and 2[illegible] feet above sea level. Somewhat detailed estimates of the capital and annual costs of the two dams are given in Tables [illegible] and 1[illegible] respectively. The layout and cross sections of the main dam and spillway for the larger reservoir are shown on Plate VI "[illegible] San Luis Rey River."



BONSALL DAM
ON
SAN LUIS REY RIVER
IN
SAN DIEGO COUNTY
1936



BONSALL DAM
ON
SAN LUIS REY RIVER
IN
SAN DIEGO COUNTY
1936

TABLE 9

COST OF BONSALL RESERVOIR

Crest of Dam Elevation - 22[illegible] feet U.S.G.S. Datum
Capacity of Reservoir to spillway li[illegible] 4[illegible],170 acre-feet
Crest of Spillway - Elevation 2[illegible] feet
Capacity of Spillway [illegible],500 second-feet
Height of Dam - 1[illegible] feet

CAPITAL COST

Dams (Main and Auxiliary)			
Excavation			
Sand and gravel	295,7[illegible] cu. yds. at .5[illegible]	147,[illegible]	
Earth and soft rock	63,7[illegible] cu. yds. at 1.[illegible]	63,7[illegible]	
Stripping	36,[illegible] cu. yds. at 2.[illegible]	72,[illegible]	
Cut off trench	3,05[illegible] cu. yds. at 2.[illegible]	6,1[illegible]	
Fill			
Impervious	67[illegible],2[illegible] cu. yds. at [illegible].4[illegible]	271,7[illegible]	
Pervious, excavation used	243,7[illegible] cu. yds. at [illegible].5	12,2[illegible]	
borrow	1[illegible],[illegible] cu. yds. at [illegible].35	35,[illegible]	
Concrete facing & cut off	13,92[illegible] cu. yds. at 12.[illegible]	167,0[illegible]	775,[illegible]
Spillway			
Excavation			
Soft rock	226,[illegible] cu. yds. at [illegible].5[illegible]	113,[illegible]	
Hard rock	114,[illegible] cu. yds. at .7[illegible]	7[illegible],[illegible]	
Concrete			
Ogee section	[illegible],2[illegible] cu. yds. at 7.5	[illegible]	
Lining	14,9[illegible] cu. yds. at 12.[illegible]	17[illegible],[illegible]	[illegible]1,[illegible]
By Pass and Outlets			
Excavation			
Hard rock	45,[illegible] cu. yds. at 7.5[illegible]	3[illegible]3,5[illegible]	
Soft rock	26,[illegible] cu. yds. at [illegible].7[illegible]	1[illegible],[illegible]	
Concrete			
Tunnel lining	1[illegible],1[illegible] cu. yds. at 2[illegible].[illegible]	2[illegible]3,[illegible]	
Tunnel plug	[illegible]950 cu. yds. at 7.5[illegible]	7,1[illegible]	
Outlet tower	(6[illegible] cu. yds. at 7.5[illegible]	[illegible]	
	(14[illegible] cu. yds. at 25.[illegible]	3,5[illegible]	
Steel			
Pipe 30"	[illegible]1,1[illegible] feet at [illegible].5[illegible]	5,3[illegible]	
Gates including trashracks etc.	5	2,[illegible]	
Needle valve 30"	1 at 6,[illegible]	[illegible]	
Slide Gate 2.5 ft. x 2.5 ft.	1 at 3,[illegible]	3,[illegible]	5[illegible],1[illegible]
Reservoir			
Lands & improvements		5[illegible]2,5[illegible]	
Relocation of roads	6 miles at 36,[illegible]	21[illegible],[illegible]	
	7 miles at 2[illegible],[illegible]	1[illegible],[illegible]	
Clearing land	7,6[illegible] acres at 2[illegible]	152,[illegible]	1,[illegible],[illegible]
sub-total			2,[illegible]61,1[illegible]

TABLE 9 (Continued)

Administration and Engineering	10% of sub total	280,100
Contingencies	15% of sub total	420,200
Interest during construction	5% rate 13 months	1[illegible]2,[illegible]00
TOTAL CAPITAL COST		3,758,300

ANNUAL COST

Interest	5 per cent per annum	187,900
Depreciation	0.35 per cent on dam only	8,300
Amortization-sinking fund	40 year 5 per cent annual payments	31,100
Operation & maintenance.	0.15 per cent per annum	5,600
TOTAL ANNUAL COST		232,900

TABLE 1[illegible]

COST OF [illegible]ONSALL RESERVOIR

Crest of Dam, Elevation 2[illegible] feet
U.S.G.S. Datum
Crest of Spillway, Elevation 240 feet
Height of Dam, 140 feet

Capacity of Reservoir to spillway lip
162,61[illegible] acre-feet
Capacity of Spillway
[illegible],5[illegible] second-feet

CAPITAL COST

Dams (Main and Auxiliary)				
Excavation				
Sand and gravel	507,10[illegible] cu. yds.	at [illegible].5[illegible]	$ 253,[illegible]	
Earth and soft rock Main dam	4[illegible],[illegible] cu. yds.	at 1.[illegible]	40,[illegible]	
Earth and soft rock Aux. dam	272,5[illegible] cu. yds.	at [illegible].5[illegible]	136,3[illegible]	
Stripping	99,1[illegible] cu. yds.	at 2.[illegible]	19[illegible],2[illegible]	
Cut off trench	5,5[illegible] cu. yds.	at 2.[illegible]	11,[illegible]	
Fill				
Impervious	1,547,6[illegible] cu. yds.	at [illegible]	73[illegible],[illegible]	
Pervious, Excavation used	726,2[illegible] cu. yds.	at [illegible].[illegible]5	36,3[illegible]	
borrow	1[illegible],[illegible] cu. yds.	at [illegible].35	35,[illegible]	
Concrete				
facing and cutoff	33,5[illegible] cu. yds.	at 12,[illegible]	4[illegible]2,[illegible]	1,[illegible]51,[illegible]
Spillway				
Excavation				
Hard rock	4[illegible],[illegible] cu. yds.	at [illegible].7[illegible]	3[illegible],[illegible]	
Soft rock	1[illegible]3,4[illegible] cu. yds.	at [illegible].5	71,7[illegible]	
Concrete				
Ogee section	1[illegible],5[illegible] cu. yds.	at 7.[illegible]	7[illegible],[illegible]	
Lining	12,1[illegible] cu. yds.	at 12,[illegible]	145,2[illegible]	32[illegible],[illegible]
By Pass and Outlets				
Excavation				
Soft rock	26,[illegible] cu. yds.	at [illegible].7[illegible]	1[illegible],[illegible]	
Hard rock	45,[illegible] cu. yds.	at 7.[illegible]	3[illegible]3,5[illegible]	
Concrete				
Tunnel lining	1[illegible],1[illegible] cu. yds.	at 2[illegible].[illegible]	2[illegible],6[illegible]	
Tunnel plug	(95[illegible] cu. yds.	at 7.5[illegible]	7,1[illegible]	
Outlet tower	(6[illegible] cu. yds.	at 7.5[illegible]	5[illegible]	
	(2[illegible] cu. yds.	at 25.[illegible]	5,5[illegible]	
Steel				
Steel pipe 42"	1,2[illegible] feet	at [illegible]	7,2[illegible]	
Gate valves incl. trashracks, etc.	7		4,[illegible]	
42" needle valve	1	at 7,5[illegible].	7,5[illegible]	
3.5 ft. x 3.5 ft. slide gate	1	at [illegible],[illegible].	[illegible],6[illegible]	[illegible]4,1[illegible]
Reservoir				
Land & improvements			6[illegible]1,2[illegible]	
Relocation of roads	6 mi.	at 36,[illegible].	216,[illegible]	
	[illegible] mi.	at 2[illegible],[illegible].	1[illegible],[illegible]	
Clearing land	[illegible],7[illegible] acres	at 2[illegible].	1[illegible],[illegible]	1,[illegible]61,2[illegible]
sub-total				4,[illegible]46,2[illegible]

TABLE 1[illegible] (Continued)

Administration and Engineering	10% of sub total	[illegible]
Contingencies	15% of sub total	6[illegible]
Interest during Construction	5% rate 1[illegible] month period	25[illegible],2[illegible]
TOTAL CAPITAL COST		[illegible],315,[illegible]

ANNUAL COST

Interest	5 per cent per annum	[illegible]65,[illegible]
Depreciation	[illegible].35 per cent per annum, [illegible] only	12,[illegible]
Amortization - sinking fund	[illegible] year 5 per cent annual payments	1[illegible],[illegible]
Operation and maintenance	[illegible].15 per cent per annum	[illegible]
TOTAL ANNUAL COST		33[illegible],6[illegible]

CHAPTER V

MONSERATE DAM AND RESERVOIR

The Monserate reservoir site is located in Sections 21, 22, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35, T. 9 S., R 2 W. and in Sections 5, 6, 7 and 8, T. 10 S., R 2 W., S. B. B. & M. The dam site is located in the Northwest one-quarter of Section 6. A topographic survey and map of the dam site, shown in Appendix "B", has been made at a scale of one inch equals one hundred feet with a contour interval of five feet.

Geology

A geologic study of the dam site was made during this investigation. In the course of this study 239 lineal feet of trench 2.5 feet wide by about 5 feet deep, 4 test pits 6 feet by 6 feet by about 10 feet deep, and about 27 surface pits and benches from 3 to 5 feet deep were dug; a six by six foot tunnel 14 feet long was dug in the right abutment; and three wells totaling 270 feet in depth were drilled in the river bed. The locations of the various workings are shown on the topographic map of the dam site in Appendix "B". Profiles showing the classification of the materials encountered are also shown on this map.

The Monserate dam site is located on the San Luis Rey River at a point where the river has cut a comparatively narrow gorge between Monserate and Lancaster Mountains. Two canyons which drain the easterly slopes of the two mountains join the river from the North and South immediately above the dam site. The left abutment is formed by a hard granite dike rising abruptly from the river bed which forms the northern spur of Lancaster mountain. The right abutment is formed by a lower ridge jutting out to the southeast from Monserate Mountain. The granites in the right abutment ridge are deeply weathered and extremely variable in type. There are a few outcroppings of hard granite but much of the material is disintegrated and badly fractured. It is probable that a fault runs down the canyon through the dam site. The

river bed between the two abutments is a level sandy plain about 800 feet wide supporting a growth of grass and Cottonwoods along the bank of the narrow surface channel which lies under the steep bluff of the left abutment.

Excavation

The left abutment dome will require only shallow surface stripping under the down stream portion of the dam. Under the upstream portion, however, doming cracks will probably require the removal of considerable hard blocky material in the preparation of a foundation for the impervious section of the dam.

The three wells drilled in the stream bed indicated that over 400 feet of this channel would have to be excavated to depths of from 80 to 100 feet below the present surface.

The explorations on the right abutment indicated that it would be necessary to excavate about 8 feet of material under the upstream portion of the dam with a further depth of 20 feet for a corewall and that, to insure the water tightness of this abutment, it would be advisable to cover a large area on its upstream face either with gunite or with an impervious clay blanket.

Comparison of Monserate and Bonsall Dam Sites

The left abutment at Monserate will require about 5 feet of excavation while that at Bonsall requires about 1 foot of stripping and 3 feet of excavation, a total of 4 feet.

The river bed at Bonsall is about 500 feet wide and requires a maximum excavation of about 55 feet in depth over a width of 130 feet while the river bed at Monserate is about 800 feet wide and will require a maximum excavation of from 80 to 100 feet in depth over a width of about 400 feet.

The right abutment at Bonsall will require a total depth of 4 feet in excavation with a 15 foot corewall while the right abutment at Monserate will require not only an 8 foot excavation with a 20 foot corewall but also a

TABLE 11

LOGS OF WELLS DRILLED AT MONSERRATE DAM SITE

Well No. 5 Depth, in feet		Well No. 6 Depth, in feet		Well No. 7 Depth, in feet	
0	Elev. 283 Sand and silt	0	Elev. 283 Sand and silt	0	Elev. 280 Sand and silt
10	Clay	18	Sand and water gravel	9	River sand & gravel
14	Water gravel	70	Blue clay	45	River gravel
16	Clay with hard streaks growing harder	74	Boulders and clay	60	Black river silt
40	Very hard decomposed granite	78	Seemed to be cemented sand wash gravel and clay.	61	Water gravel
43.5	Hard granite	104	Same with more clay	75	Boulders then into cemented sand, gravel and clay carrying wash gravel, which seemed to be in water bearing strata
45.5	Extra hard granite	106	Hard but still carrying wash gravel which seemed to be in water bearing strata	102	
46.2		122			

water tight blanket over a surface area of about 12,[illegible] square feet on its upstream face.

For these reasons it seemed probable that the Monserrate Dam would be much more costly than the Bensall Dam and, since the amount of technical help available was limited, no further studies of this site were made.